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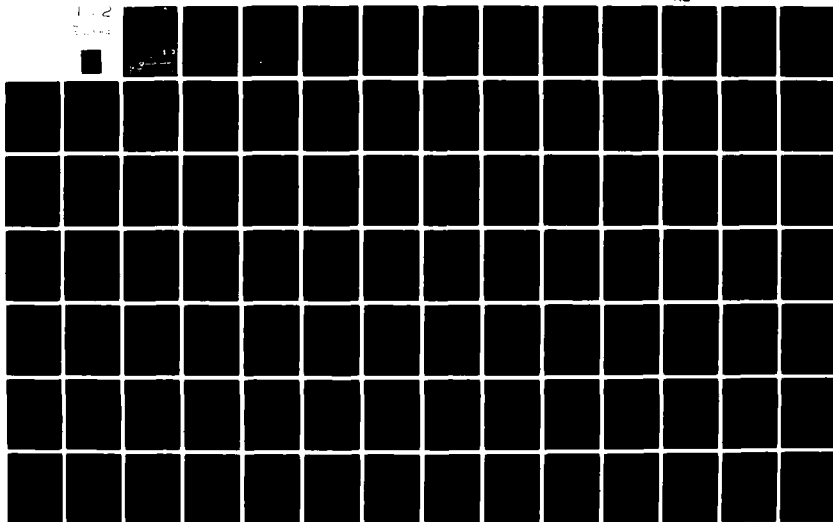
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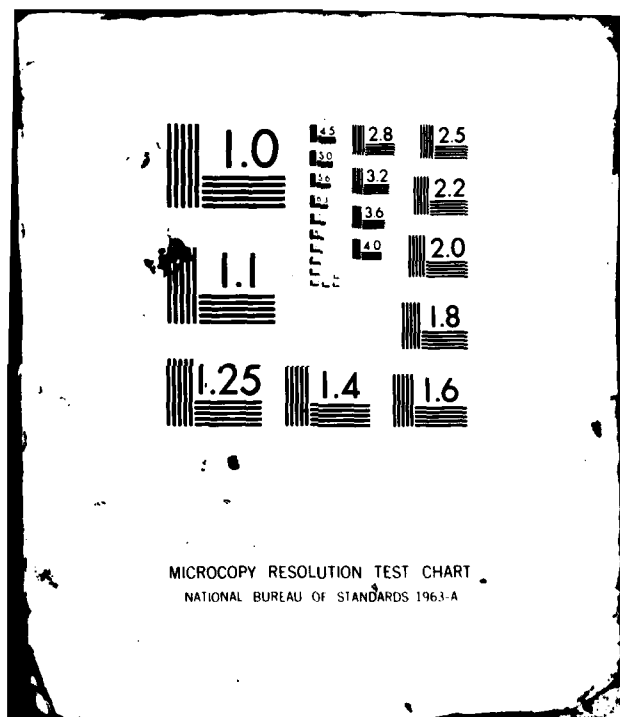
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**PSR Report 1130**

**GDEM/STANDARD OCEAN RESULTS FOR THE MEDITERRANEAN SEA**

**I. Six Selected Site Locations**

**S. C. Daubin, Jr.**  
**Pacific-Sierra Research Corporation**  
**and**  
**E. Hashimoto**  
**Ocean Data Systems, Inc.**

**December 1981**

**Final Technical Report**  
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**Naval Ocean Research and Development Activity**  
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## PREFACE

This technical report has been written in support of the Generalized Digital Environmental Model (GDEM)/Standard Ocean Evaluation Project sponsored by the Surveillance Environmental Acoustic Support (SEAS) Program at the Naval Ocean Research and Development Activity (NORDA). It evaluates GDEM MOD 03 for the Mediterranean Sea. Comparisons and evaluations have been conducted for three physical parameters for four seasons at six different selected site locations in the Mediterranean Sea. Those comparisons and evaluations were performed on vertical profiles and written as Part I.

Later in FY-82, evaluations of contoured horizontal cross-sections along selected tracks will be contained in a separate technical report - "GDEM/Standard Ocean Results for the Mediterranean Sea - Part II."

The basic data set used in this analysis is a subset of the NODC Nansen cast data base acquired by NODC through NAVOCEANO containing approximately 549,000 stations worldwide. The final six locations used in this evaluation were selected from the major ocean regions of the Mediterranean. The attempt was made in each instance to choose a location that would be geographically representative of the region and would also provide an adequate observed data sample for comparison in the immediate vicinity. The objectives were necessarily compromised in some instances, as adequate observed data were not available near each location for all seasons.

The seasonal data subsets of sound-speed profiles (computed using Wilson's (1960) equation as were the GDEM sound speeds) were processed to provide a representative or "typical" sound speed profile for each location and season. The techniques and procedures used for selection of the typical profiles is described by Colborn and Pugh (1973). The observed temperature and salinity for the typical profile were used in the comparisons for these



parameters. Plots of the typical profile and the observed minimum and maximum envelopes of values at standard depths are used to provide visual comparisons for GDEM evaluation.

It should be emphasized that the quality of the typical profile as a measure of the adequacy of GDEM is based on the quantity of data available. If the sample is small, biases can result in the typical selection. In these instances, an evaluation of the model and typical differences is restricted to general features and trends, and may be supplemented with comments regarding expected oceanographic conditions for the particular region.

The GDEM vertical profiles for comparison have been provided by Mr. Kenneth Countryman (NOO) and Dr. Michael Carron (NOO). The "typical" vertical profiles for comparison have been provided by Mr. J. Colborn, (Naval Ocean Systems Center).

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In memory of the fine work and friendship of

Scott C. Daubin, Jr.

July 1946 - August 1981

## 1.0 SUMMARY

This report evaluates the Generalized Digital Environmental Model (GDEM), developed by Dr. T. Davis of the Naval Oceanographic Office (NOO), and compares its results with observed data. Sixty-nine vertical profiles of seasonally averaged temperature, salinity, and sound speed at six different select locations were compared. The six site locations (Figure 1-1) for comparison and evaluation were located within the Alboran Sea, the Balearic Sea, the Tyrrhenian Sea, the Strait of Sicily, the Ionian Sea, and the Levantine Sea.

The comparisons and evaluations were performed on the three major physical parameters: temperature, salinity, and sound speed. The temporal resolution was seasonal (four three-month seasons) and identified as winter, spring, summer, and fall. The evaluation of each parameter was conducted in the above-listed order. Brief descriptions are provided below.

- Temperature Evaluations:

GDEM Mod 03 temperatures reflected the similarities and differences seen in the sound-speed evaluation. At most locations, temperature differences between the typical and GDEM Mod 03 profiles are small and within observational limits. In general, GDEM Mod 03 temperatures are about  $0.1^{\circ}\text{C}$  greater than the typical values.

Occasional small excursions of the model profiles beyond the observations envelopes are noted. However, because of a lack of observations or because most of those observations were obtained during one or two years, the excursions are often difficult to evaluate.

The largest temperature differences are generally noted in the upper 200 m of the profiles during the spring and autumn seasons ( $\Delta T \leq 2.5^{\circ}\text{C}$ ). Below the thermocline, GDEM temperatures and the envelope of observations approach  $\pm 0.2^{\circ}\text{C}$  of typical values. Deep GDEM temperatures agree closely with the typical values.

- Salinity Evaluations:

Overall, Mod 03 salinities are about 0.01 ppt greater than the typical salinities.

Most GDEM Mod 03 salinities lie within or close to the observational envelopes. In the upper 300 m, where most changes in the salinity are observed, the model profiles duplicate the mean trends of the typical profiles. The model frequently has difficulty duplicating the sharp features of the low salinity surface layers seen in the typical data. Rather than duplicating this layer exactly, GDEM indicates a shallower layer with similar salinities or a halocline with no layer at all.

Below 500 m, one frequently observes that the GDEM salinity profiles are about 0.05 ppt less than the minimum observed salinity. Then, below 2500 m, a slight increase is noted in all data.

- Sound-Speed Evaluations:

At most locations and seasons, GDEM Mod 03 sound speeds correctly duplicate most of the significant acoustic features seen in the typical profiles.

In instances where there are adequate observations to compare with, and when those observations are uniformly distributed in time, GDEM was found to lie within or close to the min/max envelopes of those observations. GDEM correctly indicates seasonal trends in the sound-speed profiles.

In most cases, GDEM profiles show surface layers and sound-channel axes near their correct depths and sound speeds. Half-channel characteristics are correctly indicated in the GDEM profiles during the winter season.

Overall, GDEM Mod 03 sound speeds are found to be slightly greater than the corresponding typical values; the mean sound-speed difference,  $\Delta SS$ , is about 0.33 m/sec.

In addition to seasonal comparisons and evaluations performed on vertical temperature, salinity, and sound-speed profiles, general quality assurances and checks of GDEM were conducted using T/S (Temperature/Salinity) Diagrams.

- T/S Diagrams:

GDEM T/S diagrams typically duplicate the trends seen in the observational data. In most cases, GDEM correctly duplicates the T/S characteristics of the surface water, Levantine Intermediate Water ( $T \geq 13^{\circ}\text{C}$ ,  $S \geq 38.3$  ppt), and the transition water

beneath. However, the model incorrectly represents the Mediterranean Bottom Water, showing a slight salinity increase below 2500 m ( $\leq 0.05$  ppt) rather than the observed slight decrease. The difference results in a spurious hook in the T/S diagrams. This increase and the generally lower salinities above might be due to a salinity adjustment applied to ensure stability of the model's water column. Apparently, this correction is applied so that values of  $\sigma_{STO}$ , the potential density at the surface, monotonically increases with depth. Considering the adiabatic temperature increase with depth below 2500 m, the more realistic approach to the stability adjustment might be to adjust salinity (if necessary) so that the in situ density,  $\sigma_{STD}$ , increases or remains constant with depth. Alternatively, the potential temperature  $\theta$  might be used in the density calculation rather than the higher in situ temperature, T. Either solution might reduce the slight salinity differences. These salinity differences as well as those noted above are not expected to significantly alter the GDEM sound-speed values; sound-speed differences due to those anomalies should all be less than 0.2 m/sec.

In summary, GDEM adequately reproduces most mesoscale sound-speed, temperature, and salinity features at the locations analyzed. However, occasional differences in detail do exist.

Seasonal changes in the upper 500 m of the model data are similar to the observed values. GDEM T/S relationships are similar to the observational data above 2500 m; below this depth, there is an anomalous (but slight) 0.05 ppt salinity increase. Apparently, this salinity anomaly results from an adjustment of the GDEM salinities so that  $\sigma_{STO}$  remains constant or increases with depth. A more realistic deep salinity field might result if the in situ density,  $\sigma_{STD}$ , or the potential temperature  $\theta$  in the  $\sigma_{STO}$  calculation were used.

GDEM Mod 03 matches the typicals most closely in winter and summer. In the region of the Strait of Sicily, we observed large variability in sound speed, temperature and salinity. The largest sound-speed differences occasionally occur during the transition seasons of spring and autumn.

Those large differences are found predominantly in the upper 200 m of the profiles and are directly related to large temperature or salinity (in some cases) differences at these depths. It is not always possible to determine their significance because there are few real observations with which to compare and/or most observations were taken during one or two years. For example, at location Med 4 - autumn, we compared GDEM with only six observations, all taken in 1949.

During seasons when there is a sound-channel axis present, GDEM Mod 03 values of the axis depth are usually within  $\approx 50$  m of the typical values. However, at locations Med 5 - summer and autumn, and Med 6 - spring, larger axis-depth differences are noted. At Med 5 - autumn, the typical axis depth is 75 m while GDEM Mod 03 indicates a broad minima near 300 m. It should be noted, though, that there is only one observation for Med 5 - autumn. At Med 6 - spring, there are 15 observations indicating an axis between 85 m and 420 m with a typical depth of 300 m. GDEM Mod 03 shows this minima between 400 and 500 m near the maximum observed axis depth.

In an effort to summarize the seasonal temperature, salinity, and sound-speed evaluations for each selected site location, brief evaluations and comments are presented in Tables 1-1 through 1-4 by location, parameter, and season.

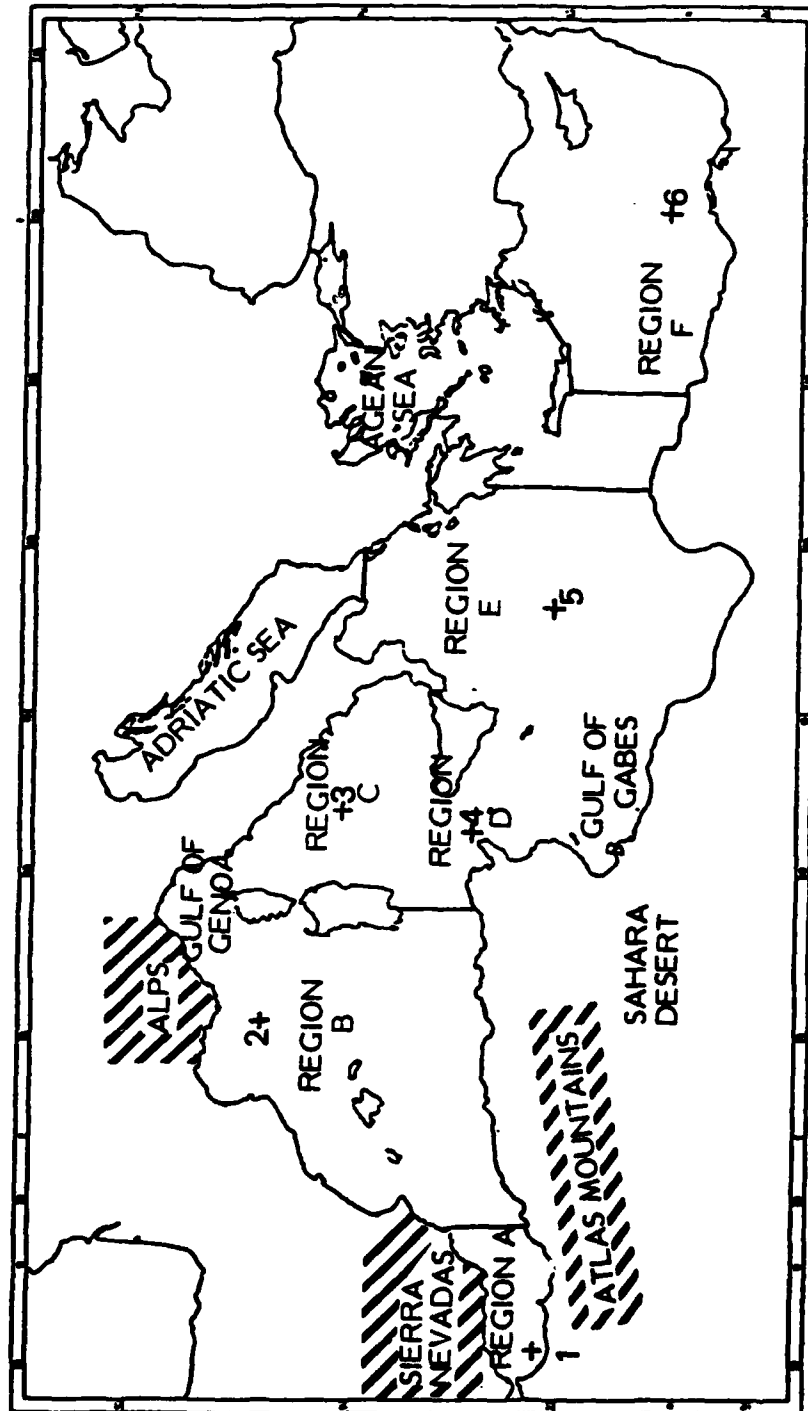


FIG. 1-1. GEOGRAPHIC LOCATIONS OF VERTICAL COMPARISON SITES AND PHYSICAL FEATURES FOR MEDITERRANEAN SEA

TABLE 1-1: SUMMARY OF GDEM/STANDARD OCEAN  
WINTER SITE EVALUATION

SITE	WINTER			COMMENTS
	Temperature	Salinity	Sound Speed	
Med Location #1 (Alboran Sea)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.10 - 0.15 ppt)
Med Location #2 (Balearic Sea)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.08 - 0.12 ppt)
Med Location #3 (Tyrrhenian Sea)	Reasonable and Seasonally Averaged	Reasonable and Seasonally Averaged	Reasonable and Seasonally Averaged	
Med Location #4 (Strait of Sicily)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.08 - 0.15 ppt)
Med Location #5 (Ionian Sea)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.11 ppt)
Med Location #6 (Levantine Sea)	Reasonable and Seasonally Averaged	Reasonable and Seasonally Averaged	Reasonable and Seasonally Averaged	

\*The differences noted have been brought to the attention of Dr. T. Davis (NOO). Undergoing constructive improvements and modifications, GDEM Mod 04 (currently under development) will contain several revisions that will address those differences and improve the temporal resolution of GDEM Mod 03. At this time, a documentation of the revisions along with their results is anticipated to follow.



TABLE 1-2: SUMMARY OF GDEM/STANDARD OCEAN  
SPRING SITE EVALUATION

SITE	SPRING			COMMENTS
	Temperature	Salinity	Sound Speed	
Med Location #1 (Alboran Sea)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.25 - 0.30 ppt)
Med Location #2 (Balearic Sea)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.11 ppt)
Med Location #3 (Tyrrhenian Sea)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.08 - 0.13 ppt)
Med Location #4 (Strait of Sicily)	Reconsider	Acceptable and Seasonally Averaged	Modify	●GDEM temperature* too high (75-200 m) ●Possibly increase* salinity (0.14 ppt) ●GDEM sound speed* consistently high
Med Location #5 (Ionian Sea)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.11 ppt)
Med Location #6 (Levantine Sea)	Reasonable and Seasonally Averaged	Reasonable and Seasonally Averaged	Reasonable and Seasonally Averaged	

\*The differences noted have been brought to the attention of Dr. T. Davis (NOO). Undergoing constructive improvements and modifications, GDEM Mod #4 (currently under development) will contain several revisions that will address those differences and improve the temporal resolution of GDEM Mod #3. At this time, a documentation of the revisions along with their results is anticipated to follow.

TABLE 1-3: SUMMARY OF GDEM/STANDARD OCEAN  
SUMMER SITE EVALUATION

SITE	SUMMER			COMMENTS
	Temperature	Salinity	Sound Speed	
Med Location #1 (Alboran Sea)	Reasonable and Seasonally Averaged	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	●Over suppression* on sound speed profile at 200 m.
Med Location #2 (Balearic Sea)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.08 - 0.12 ppt)
Med Location #3 (Tyrrhenian Sea)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.08 - 0.10 ppt)
Med Location #4 (Strait of Sicily)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.06 ppt)
Med Location #5 (Ionian Sea)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.07 ppt)
Med Location #6 (Levantine Sea)	Reasonable and Seasonally Averaged	Reasonable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Salinity gradient* reversals remarkably reproduced.

\*The differences noted have been brought to the attention of Dr. T. Davis (NOO). Undergoing constructive improvements and modifications, GDEM Mod 04 (currently under development) will contain several revisions that will address those differences and improve the temporal resolution of GDEM Mod 03. At this time, a documentation of the revisions along with their results is anticipated to follow.

TABLE 1-4: SUMMARY OF GDEM/STANDARD OCEAN  
FALL SITE EVALUATION

SITE	FALL			COMMENTS
	Temperature	Salinity	Sound Speed	
Med Location #1 (Alboran Sea)	No evaluation	No evaluation	No evaluation	
Med Location #2 (Balearic Sea)	Reasonable and Seasonally Averaged	Acceptable Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.12 ppt)
Med Location #3 (Tyrrhenian Sea)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Possibly increase* salinity (0.05 - 0.13 ppt)
Med Location #4 (Strait of Sicily)	Reasonable and Seasonally Averaged	Acceptable and Seasonally Averaged	Reasonable and Seasonally Averaged	●Consider a* surface salinity minimum layer
Med Location #5 (Ionian Sea)	Reasonable and Seasonally Averaged	Reconsider	Modify	●Possibly increase* salinity (0.15 ppt) ●Difference in* salinity maximums ●Secondary sound* channel axis not seasonally persistent feature
Med Location #6 (Levantine Sea)	Reasonable and Seasonally Averaged	Reasonable and Seasonally Averaged	Reasonable and Seasonally Averaged	

\*The differences noted have been brought to the attention of Dr. T. Davis (NOO). Undergoing constructive improvements and modifications, GDEM Mod #4 (currently under development) will contain several revisions that will address those differences and improve the temporal resolution of GDEM Mod #3. At this time, a documentation of the revisions along with their results is anticipated to follow.

## 2.0 VERTICAL TEMPERATURE, SALINITY, AND SOUND-SPEED PROFILE COMPARISONS FOR MEDITERRANEAN (MED) LOCATION #1

Nine Vertical comparisons of temperature (T), salinity (S), and sound-speed (SS) for the winter, spring, and summer seasons\* are presented in this section. Comparisons for the fall season\* are not presented because of insufficient data for the selection of typical profiles.

### 2.1 Description

Med Location #1 is taken from the Alboran Sea region of the Mediterranean Sea. The geographical location selected for this comparison is at 35°30' north latitude and 004°30' west longitude. Vertical temperature, salinity, and sound-speed profiles of seasonal comparisons for three seasons are shown in Figures 2-1 through 2-9.

The Alboran Sea region of the western Mediterranean Sea, depicted as Region A on Figure 1-1, is defined for this report as the body of water that is bounded to the north by the southern coastline of Spain; to the south by the northern coastline of Morocco and Algeria; to the west by the Strait of Gibraltar, and to the east by 1° west longitude.

Meteorologically, this region is considered highly variable and seasonally influenced to a great degree by the movement of the semi-permanent Azores anticyclone. In most cases, the local to semilocal surface wind conditions are not produced by the distinct wind patterns associated with either the Sierra Nevada of Spain or the Atlas Mountains of Morocco and Algeria. Channeling and corner effects dominate the local wind patterns in this region. An area of cyclogenesis for the western portion has been identified as being in the center of the Alboran Sea.

Oceanographically, this region is considered to be highly active, extremely variable, and sufficiently influenced by a number of surface and sub-surface physical features, e.g. ocean fronts, ocean eddies, current boundaries, and zones of convergence/divergence.

\*Seasons: Winter=January to March; Spring=April to June; Summer=July to September; Fall=October to December.

Proper environmental numerical modeling of this region is problematic. Substantial dynamic activity and variability make proper representation of typical conditions extremely difficult. Past studies of this region have indicated the development and presence of a noticeable summer oceanic front. More recent studies have shown that the Alboran Sea front is not a summer feature, but a persistent feature that can be identified throughout the year (Cheney, 1977). The frontal system extends in a general eastward pattern establishing cyclonic and anticyclonic gyres. Large amounts of North Atlantic water flow through the Strait of Gibraltar, providing a source for warm water as well as exerting some influence on the meanderings of the front.

## 2.2 Comparisons for Location #1

The vertical site comparisons of seasonal temperature, salinity, and sound-speed profiles, respectively, are presented for Med Location #1.

- Temperature:

The January-to-March temperature envelope taken from the statistical summaries was based on a data sample size of 14 observations (Figure 2-1). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only  $0.05^{\circ}\text{C}$ . Differences in value between the surface and the 100 m level are less than  $0.08^{\circ}\text{C}$ . Differences at the 125, 150, and 200 m levels are only  $0.33^{\circ}\text{C}$ ,  $0.47^{\circ}\text{C}$ , and  $0.33^{\circ}\text{C}$ , respectively.

The April-to-June temperature envelope taken from the statistical summaries was based on a data sample size of eight observations (Figure 2-2). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only  $0.19^{\circ}\text{C}$ . Differences in value between the surface and 30 m do not exceed  $0.06^{\circ}\text{C}$ . Differences at the 50, 75, and 100 m levels are only  $0.44^{\circ}\text{C}$ ,  $0.76^{\circ}\text{C}$ , and  $0.61^{\circ}\text{C}$ , respectively. Differences at 150 and 200 m are  $0.32^{\circ}\text{C}$  and  $0.51^{\circ}\text{C}$ , respectively. Below 200 m, the differences do not exceed  $0.07^{\circ}\text{C}$ .

The July-to-September temperature envelope taken from the statistical summaries was based on a data sample size of 50 observations (Figure 2-3). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by  $1.31^{\circ}\text{C}$ . Differences in value between the surface and 50 m vary up to  $1.70^{\circ}\text{C}$ . Below 75 m, the differences are less than  $0.44^{\circ}\text{C}$  to 125 m. Below 150 m, the differences do not exceed  $0.22^{\circ}\text{C}$ .

The October-to-December temperature comparison is not available because of insufficient data.

- **Salinity:**

The January-to-March salinity envelope taken from the statistical summaries was based on a data sample size of 14 observations (Figure 2-4). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.05 ppt. Differences between the 10 and 150 m levels do not exceed 0.06 ppt. A difference of 0.31 ppt exists at 200 m. Below 200 m, there exist differences on the order of 0.18 ppt.

The April-to-June salinity envelope taken from the statistical summaries was based on a data sample size of eight observations (Figure 2-5). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.01 ppt. Various differences in numerical value are found between the profiles with depth. Between 20 to 50 m, the differences do not exceed 0.19 ppt. Between 75 to 100 m, the differences are on the order of 0.34 ppt. At 125 m the difference is 0.01 ppt. With the exception of the 200 m level, which has a difference of 0.38 ppt, the differences between the 150 to 400 m levels range near 0.30 ppt.

The July-to-September salinity envelope taken from the statistical summaries was based on a data sample size of 50 observations (Figure 2-6). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.12 ppt. Differences not exceeding 0.33 ppt exist between 10 and 50 m. Between the 75 and 150 m levels, the differences range from 0.41 ppt to 0.84 ppt. Below 200 m, the differences do not exceed 0.23 ppt.

The October-to-December salinity comparison is not available because of insufficient data.

- **Sound Speed:**

The January-to-March sound-speed envelope taken from the statistical summaries was based on a data sample size of 14 observations (Figure 2-7). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.1 m/s. Differences in GDEM value between the 10 to 100 m levels do not exceed 0.2 m/s. A difference of 1.4 m/s is found at the 150 m level. Below 200 m, the differences do not exceed 0.5 m/s.

The April-to-June sound-speed envelope taken from the statistical summaries was based on a data sample size of eight observations (Figure 2-8). The GDEM value at the surface falls within the envelope of observed values and differs from the typical by only

0.5 m/s. Various differences exist between 10 and 400 m. With the exception of the 50, 75, 100 and 200 m levels, which have differences of 1.1 m/s, 2.4 m/s, 1.4 m/s and 1.3 m/s respectively, the differences do not exceed 0.8 m/s.

The July-to-September sound-speed envelope taken from the statistical summaries was based on a data sample size of 50 observations (Figure 2-9). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by 3.1 m/s. Various differences exist between 10 and 400 m. Between 10 and 50 m, differences range from 2.6 m/s to 4.5 m/s. Between 100 to 150 m, differences range from 1.2 m/s to 2.4 m/s. The 75, 200, 250, 300 and 400 m level differences do not exceed 0.7 m/s.

The October-to-December sound speed comparison is not available because of insufficient data.

### 2.3 Evaluation - Alboran Sea (Location #1)

- January to March:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in the thermal structures. The absolute values defining the thermocline region differ (by only 0.3 to 0.4 °C); however, the general trend of the thermocline gradients is similar. This ocean region is known for its very high variability and physical processes. The envelope of observed values is substantially wide for winter structuring and reflects a zone of noticeable thermal variability. GDEM appears to reflect a predominant and reasonable seasonally averaged winter thermal structure for this extremely variable ocean region when compared with the 14 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals similarities in the haline structures. The absolute values defining the halocline region differ (by only 0.05 ppt to 0.3 ppt); however, the general trend of the halocline gradients is similar. The wide and undulating silhouette of the envelope of observed values is quite deep and is indicative of a region of persistent and strong haline variability. GDEM appears to reflect a predominant and reasonable seasonally averaged winter haline structure for this extremely variable ocean region when compared with the 14 usable observations. In addition, the numerical value of the GDEM salinity below 300 m can perhaps be increased by approximately 0.10 to 0.15 ppt.

An evaluation of the GDEM and typical sound-speed profile comparison reveals similarities in the general near-surface and below-axis portion of the profiles. There appears to be a difference in the depths of the subsurface maximas of approximately 25 m and a

difference in numerical value between the maximas of only 0.6 m/s. The difference in the depth of the subsurface maximas appears to be reasonable within the envelope of observed values. There appears to be a difference of 1.4 m/s at 150 m; however, that difference occurs within an envelope of variability of approximately 5.1 m/s. The difference in the GDEM and typical sonocline gradients between 100 to 200 m appears to be caused predominantly by differences in the temperature structure at those depth levels. GDEM appears to reflect a predominant and reasonable seasonally averaged winter sound-speed structure for this extremely variable ocean region when compared with the particular 14 usable observations.

- April to June:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in the thermal structures. The absolute values defining the thermocline region differ (by less than 0.76°C); however, the general trend of the thermocline gradients is similar. This ocean region is known for its very high variability and physical processes. The envelope of observed values is substantially wide for spring structuring and reflects a zone for noticeable thermal variability. GDEM appears to reflect a predominant and reasonable seasonally averaged spring thermal structure for this extremely variable ocean region when compared with the eight usable observations.

An evaluation of the GDEM and typical salinity profile comparison appears to reveal general similarities in the haline structure. The GDEM subsurface haline minima differs by approximately 0.3 ppt; however, the envelope of observed values is substantially wide throughout the halocline region and reflects an ample zone for spring haline structuring. GDEM appears to reflect a predominant and reasonable seasonally averaged spring haline structure for this extremely variable ocean region when compared with the eight usable observations. In addition, the numerical value of the GDEM salinity below 200 m can perhaps be increased by approximately 0.25 ppt to 0.30 ppt.

An evaluation of the GDEM and typical sound-speed profile comparison reveals general similarities in the near-surface and below-axis portion of the profiles. There appears to be differences in the depth placements and numerical values of the undulating sonoclines. Those differences, however, are 1.1 m/s to 2.1 m/s differences occurring within an envelope of variability having a magnitude of approximately 6.0 m/s. The undulations within the sonocline are directly related to the undulations reflected in the GDEM



thermocline structure. There is a vertical displacement of the depths of the sound channel axes of approximately 50 m. GDEM appears to reflect a predominant and reasonable seasonally averaged spring sound-speed structure for this extremely variable ocean region when compared with the particular eight usable observations.

- July to September:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in the thermal structures. The absolute values defining the thermocline region differ (by less than  $1.7^{\circ}\text{C}$ ). However, the envelope of thermal variability near this region of difference has a magnitude of approximately  $5.8^{\circ}\text{C}$ . This ocean region is known for its very high variability and physical processes. The envelope of observed values is substantially wide for summer structuring and reflects a zone of noticeable thermal variability. GDEM appears to reflect a predominant and reasonable seasonally averaged summer thermal structure for this extremely variable ocean region when compared with the 50 usable observations.

An evaluation of the GDEM and typical salinity profile comparison appears to reveal general similarities in the haline structure (surface minimas and subsurface maximas). A noticeable difference appears to occur at 125 m. The typical reflects a definite halocline layer whereas the GDEM does not. Both the GDEM and the typical at 125 m remain within a very wide envelope of variability. The halocline layer of the typical at 125 m appears to be reflecting an observation that is defining the minimum portion of the envelope, whereas the GDEM profile through the halocline region tends to reflect an average or mean trend within the very wide envelope. This ocean region is known for its very high variability and physical processes. The envelope of observed values is substantially wide throughout the halocline region and reflects an ample zone for summer haline structuring. GDEM appears to reflect a predominant and reasonable seasonally averaged summer haline structure for this extremely variable ocean region when compared with the 50 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals similarities in the near-surface and below-axis portion of the profiles. There appear to be differences in the structure of the sonocline region, as well as in the strength of the upper portion of the apex of the sound-channel axis. The envelope of variability through the undulating portion of the GDEM sonocline is very wide (approximately 9.5 m/s to 15.2 m/s between 50 and 125 m). Undulating features can realistically occur within a

region of high variability, physical processes, and broad max/min ranges. The difference in the strength (curvature) immediately above (at approximately 200 m) of the GDEM sound-channel axis is noticeably suppressed downward. This suppression can be directly attributed to a similar feature found on the GDEM temperature profile. This suppression is not considered historically representative. The depths of the sound-channel axes are similar. With the exception of the suppression in the sound-speed profile, the GDEM profile appears to reflect an acceptable and reasonable seasonally averaged summer sound-speed structure for this extremely variable ocean region when compared with the 50 usable observations.

- October to December:

Evaluation for this time period is not available because of the lack of usable data.

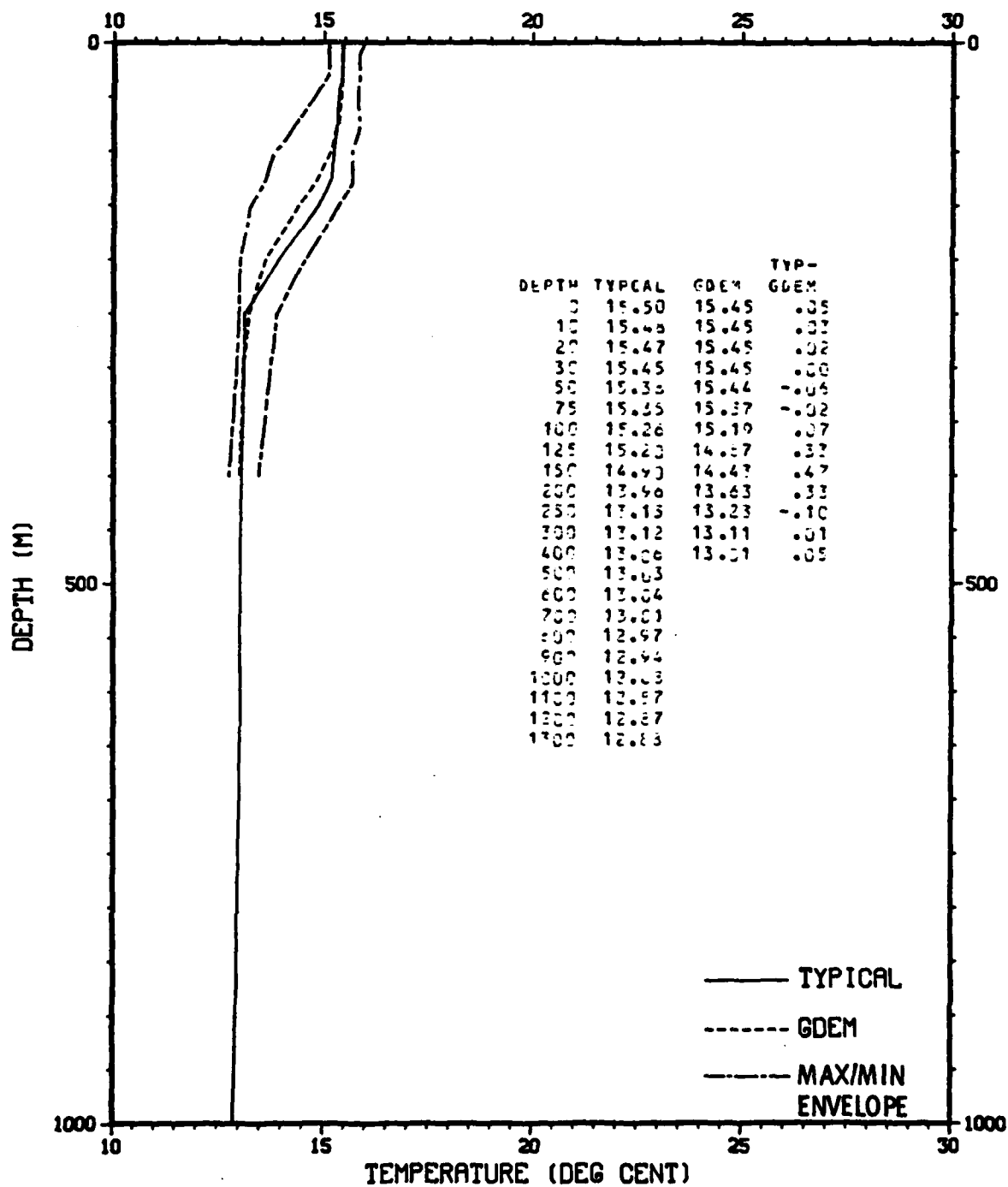


FIG. 2-1. VERTICAL TEMPERATURE PROFILE FOR ALBORAN SEA (JAN - MAR)

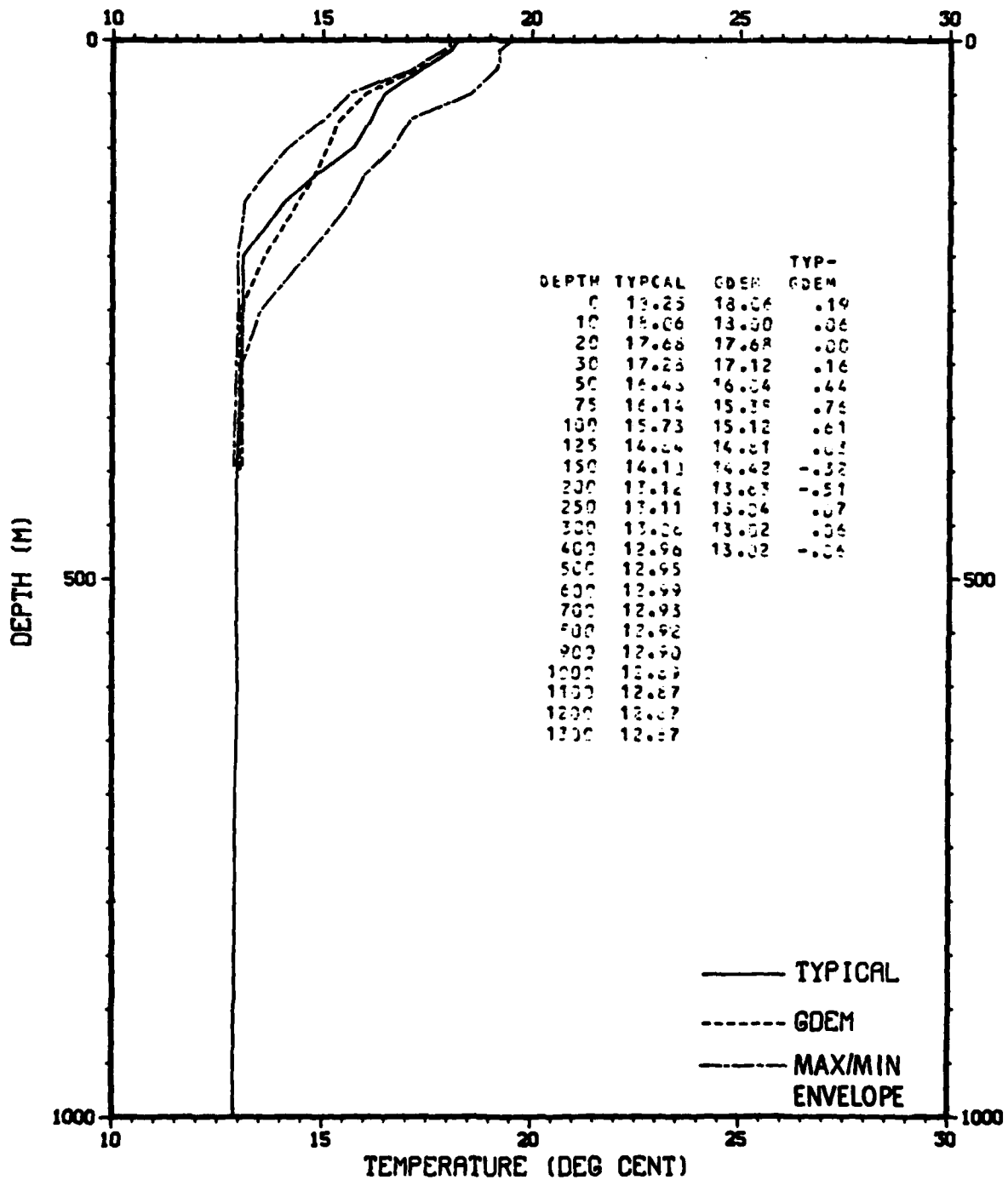


FIG. 2-2. VERTICAL TEMPERATURE PROFILE FOR ALBORAN SEA (APR - JUN)

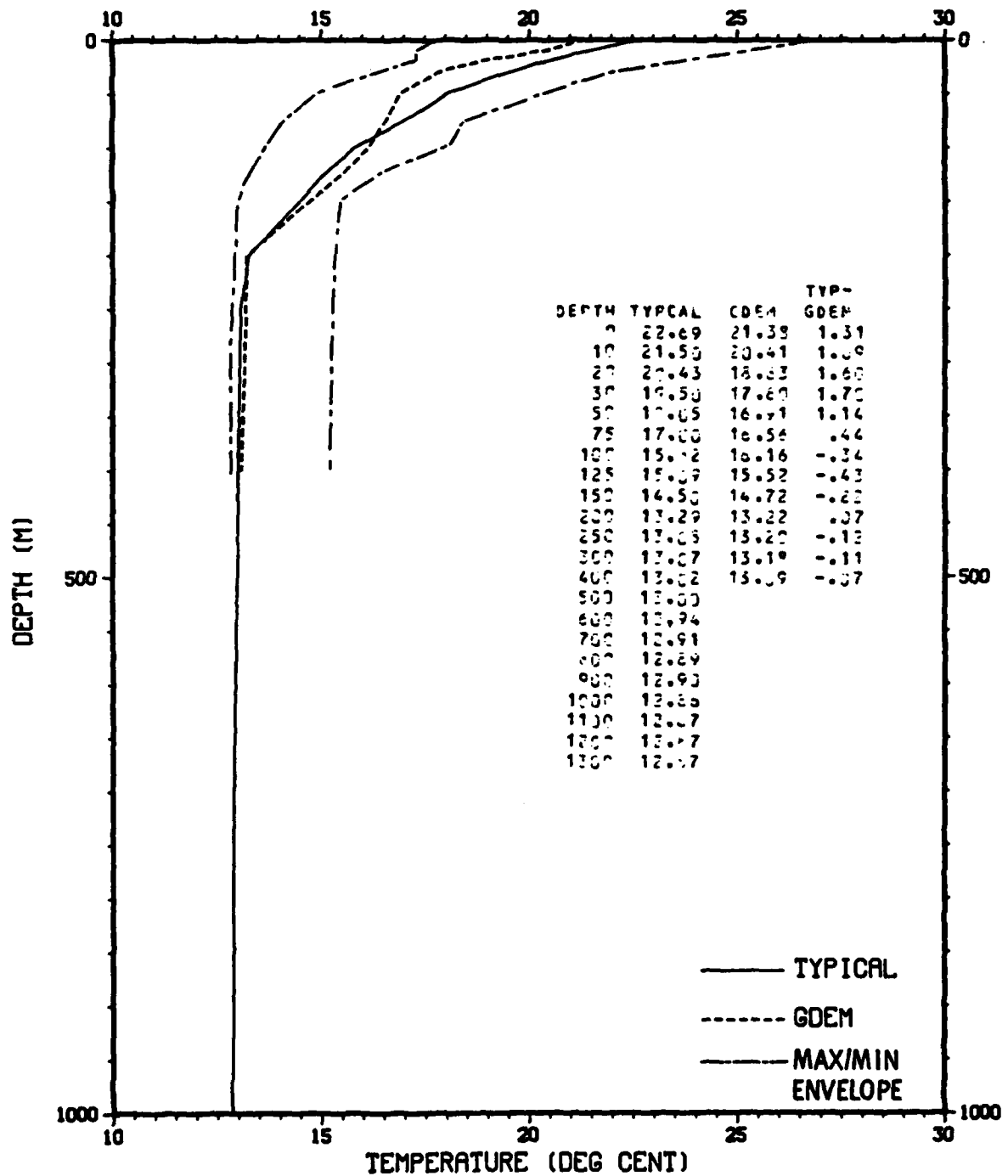


FIG. 2-3. VERTICAL TEMPERATURE PROFILE FOR ALBORAN SEA (JUL - SEP)

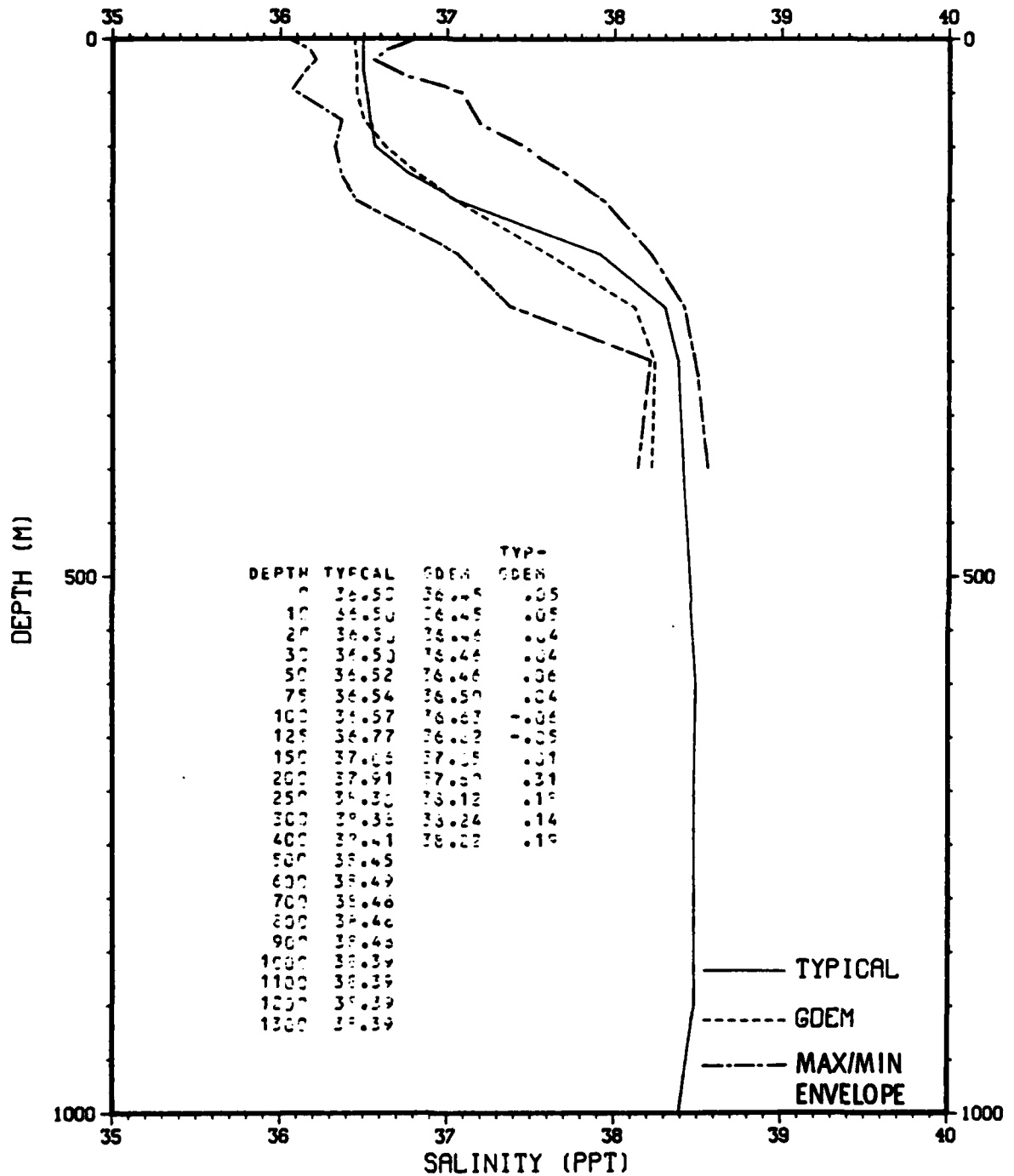


FIG. 2-4. VERTICAL SALINITY PROFILE FOR ALBORAN SEA (JAN - MAR)

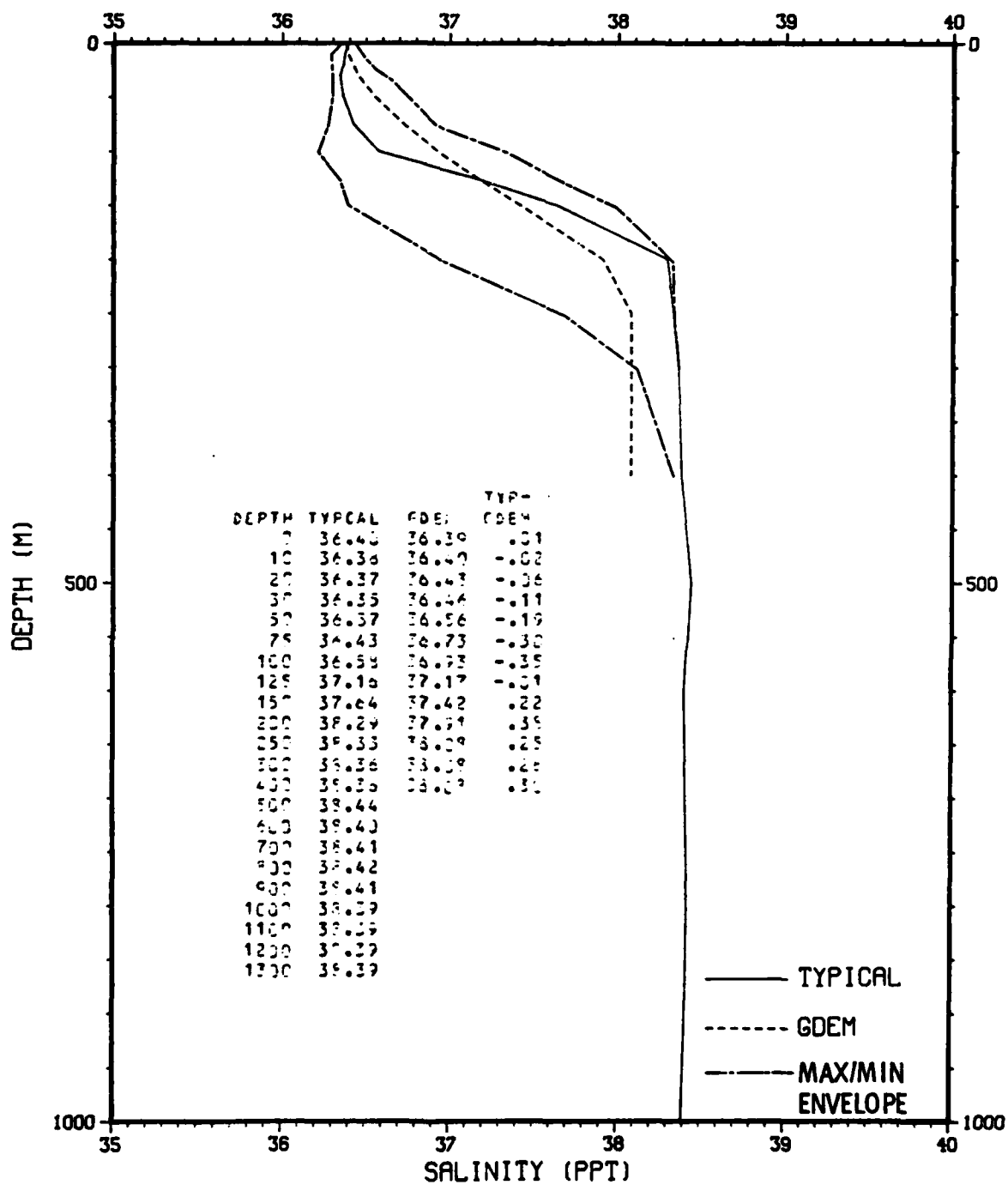


FIG. 2-5. VERTICAL SALINITY PROFILE FOR ALBORAN SEA (APR - JUN)

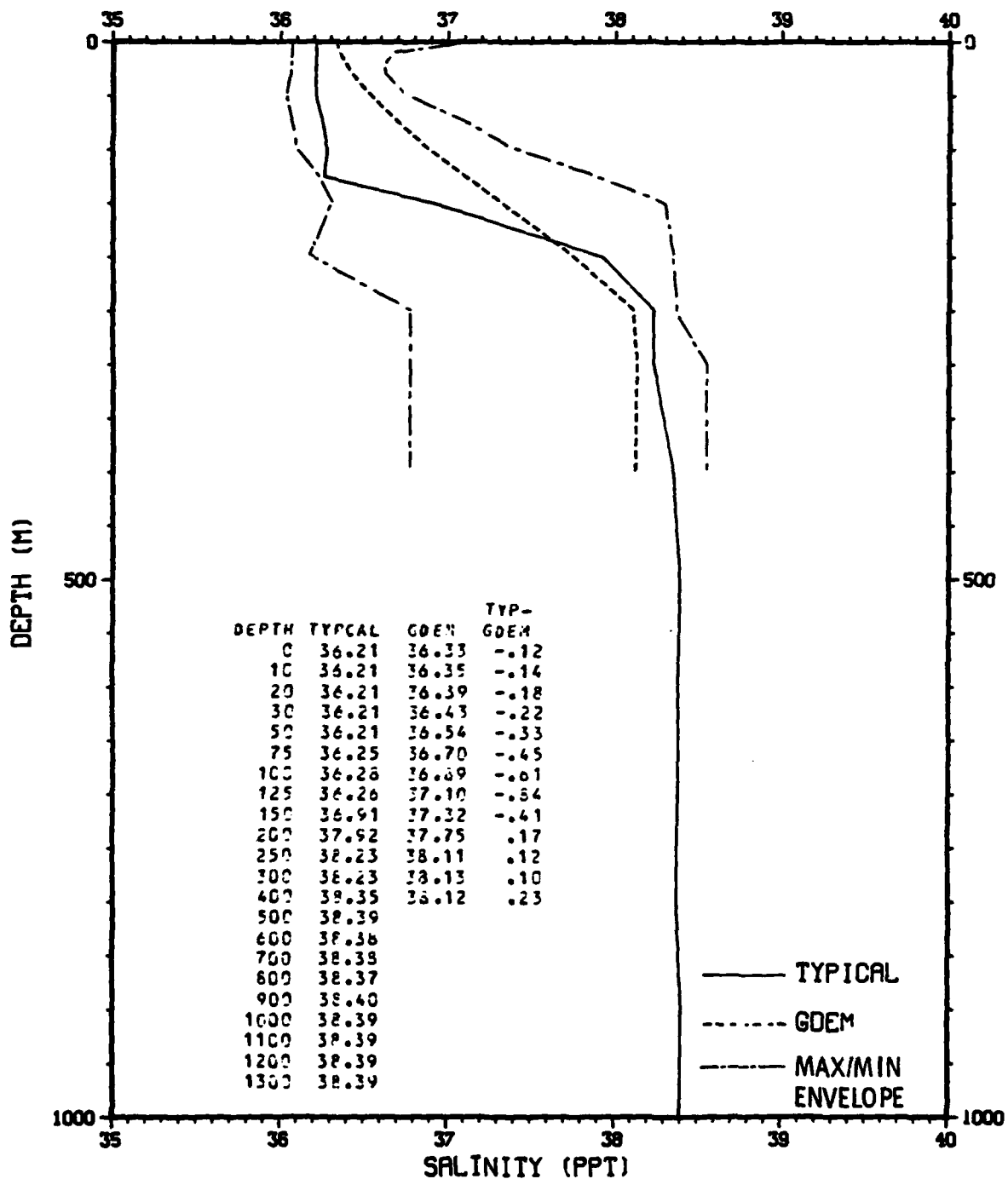


FIG. 2-6. VERTICAL SALINITY PROFILE FOR ALBORAN SEA (JUL - SEP)



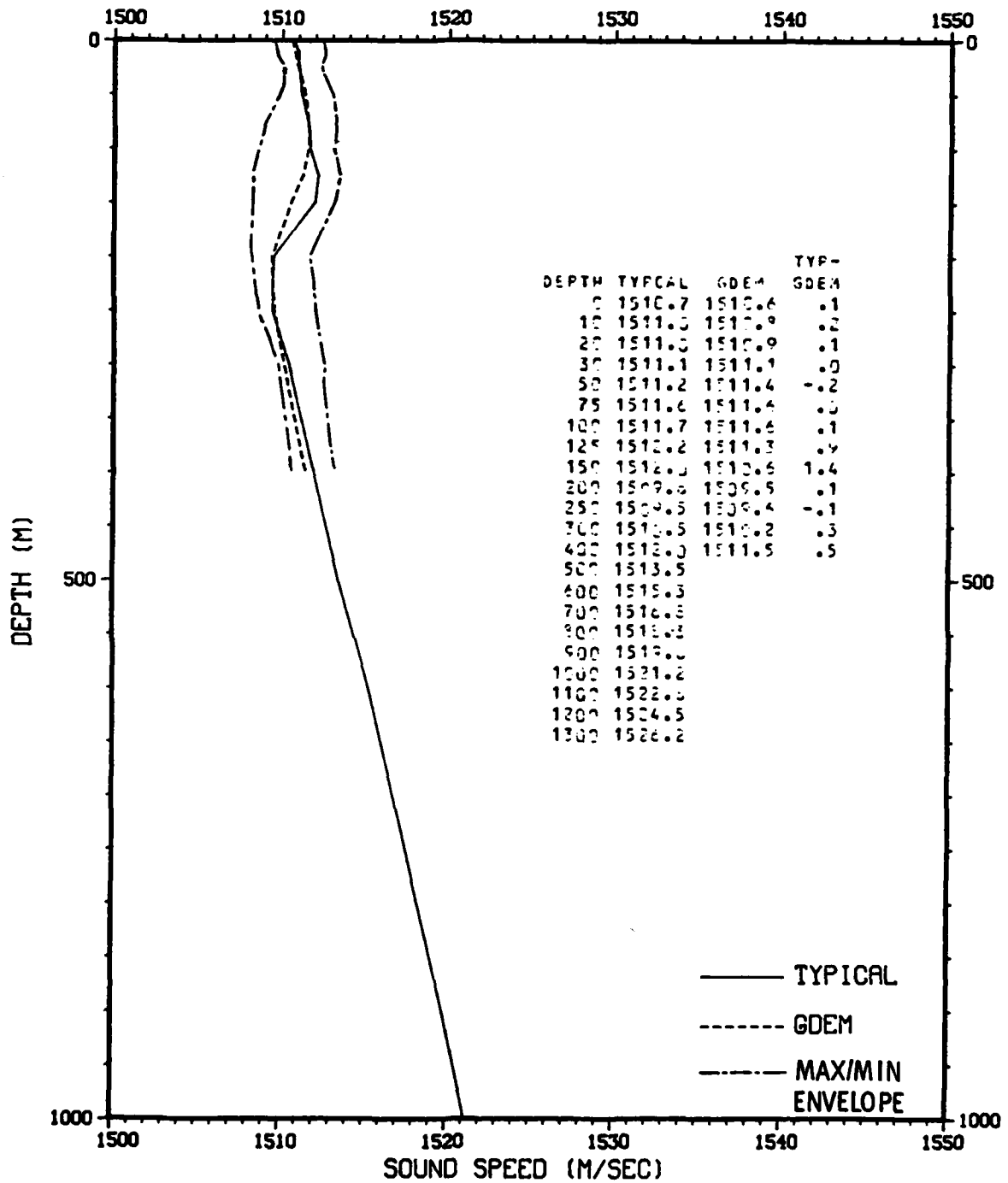


FIG. 2-7. VERTICAL SOUND-SPEED PROFILE FOR ALBORAN SEA (JAN - MAR)

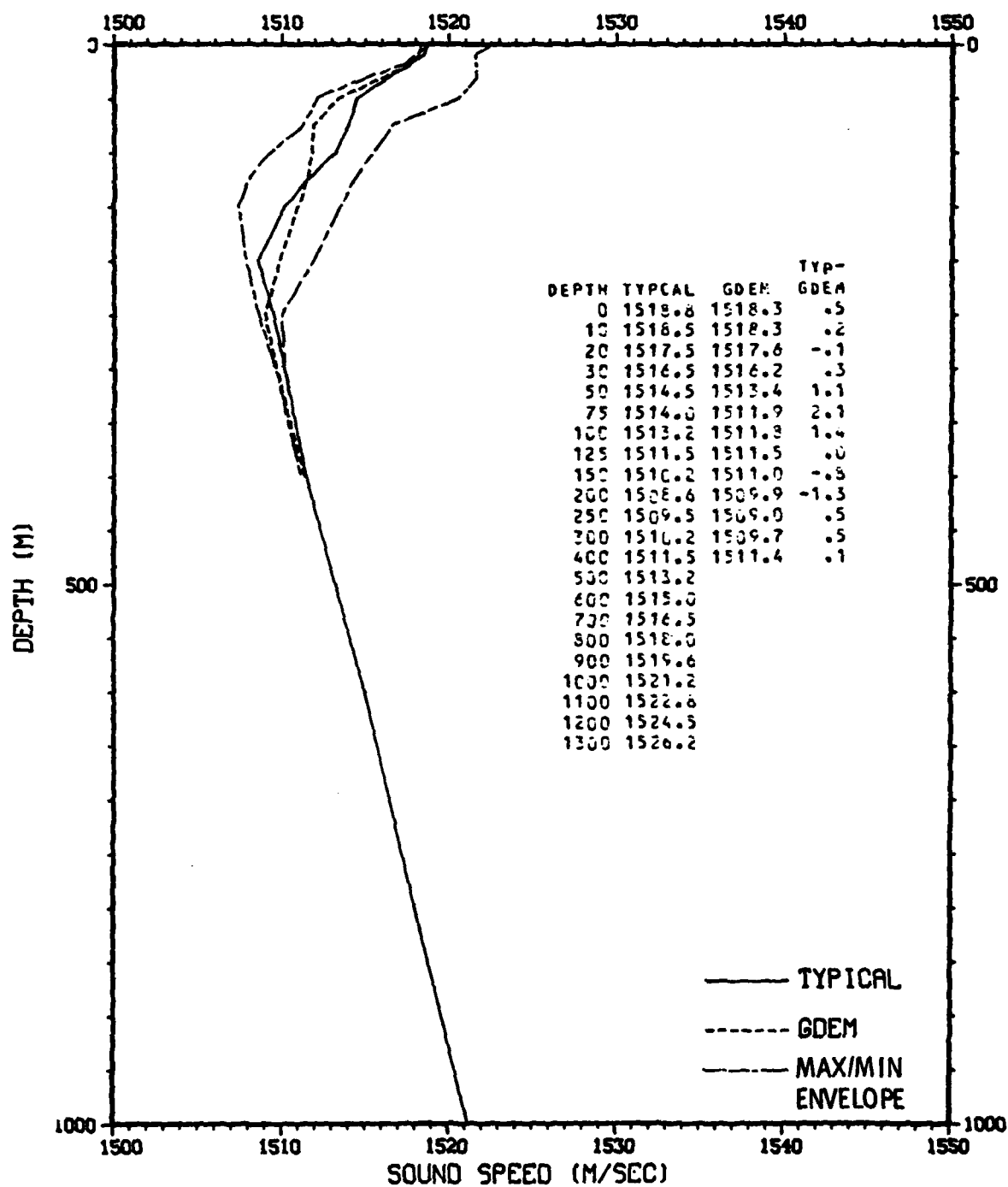


FIG. 2-8. VERTICAL SOUND-SPEED PROFILE FOR ALBORAN SEA (APR - JUN)

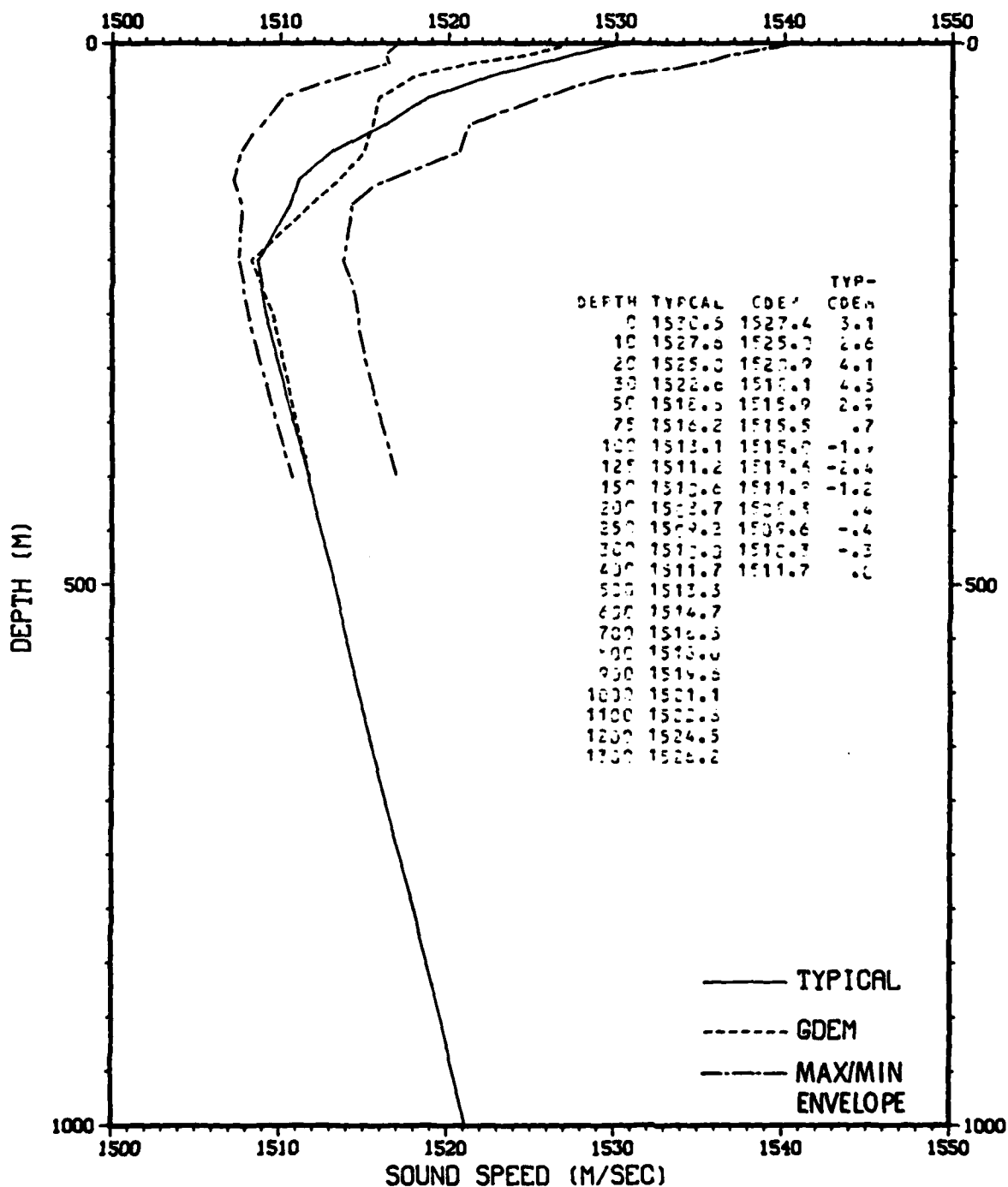


FIG. 2-9. VERTICAL SOUND-SPEED PROFILE FOR ALBORAN SEA (JUL - SEP)

### 3.0 VERTICAL TEMPERATURE, SALINITY, AND SOUND-SPEED PROFILE COMPARISONS FOR MEDITERRANEAN (MED) LOCATION #2

Twelve vertical comparisons of temperature (T), salinity (S), and sound-speed (SS) for winter, spring, summer, and fall seasons are presented in this section.

#### 3.1 Description

Med Location #2 is taken from the Balearic Sea region of the Mediterranean Sea. The geographical location selected for this comparison is at  $42^{\circ}00'$  north latitude and  $006^{\circ}00'$  east longitude. Vertical temperature, salinity, and sound-speed profiles of seasonal comparisons are shown in Figures 3-1 through 3-12.

The Balearic Sea region of the western central Mediterranean Sea, depicted as Region B on Figure 1-1, is defined for this report as the body of water that is bounded to the west by  $1^{\circ}$  west longitude and the east coastline of Spain; to the north by the southern coastline of France; to the east by the islands of Corsica and Sardinia; and to the south by the coastline of Algeria.

Meteorologically, this region is considered active, variable, and seasonally influenced by an area that is known for cyclogenesis. This area is located off the eastern coast of Spain in the Balearic Sea and encompasses the Balearic Islands. Cyclogenesis over the Balearic Sea is frequently found in the winter, with common occurrences in the spring and fall.

Oceanographically, this region is considered highly variable. The ocean variability and changes in the vertical and horizontal structuring are direct and substantial responses to the variable and seasonal impulses generated from the nearby zone of cyclogenesis. Seasonal effects of mechanical mixing are generally confined to the near-surface structure.

#### 3.2 Comparisons For Location #2

The vertical site comparisons of seasonal temperature, salinity, and sound-speed profiles, respectively, are presented for Med Location #2.

- Temperature:

The January-to-March temperature envelope taken from the statistical summaries was based on a sample size of 85 observations (Figure 3-1). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only  $0.12^{\circ}\text{C}$ . Differences in value of GDEM from the surface to 2000 m do not exceed  $0.19^{\circ}\text{C}$ .

The April-to-June temperature envelope taken from the statistical summaries was based on a data sample size of nine observations (Figure 3-2). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by  $1.33^{\circ}\text{C}$ . At 10 m, there is a difference of  $0.73^{\circ}\text{C}$ , and at 50 m a  $0.37^{\circ}\text{C}$  difference. Between 75 and 600 m, numerical differences are less than  $0.29^{\circ}\text{C}$ . Below 600 m, down to 2000 m, the differences do not exceed  $0.06^{\circ}\text{C}$ .

The July-to-September temperature envelope taken from the statistical summaries was based on a sample size of 21 observations (Figure 3-3). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by  $1.14^{\circ}\text{C}$ . Differences at the 10, 20, and 30 m levels are  $1.47^{\circ}\text{C}$ ,  $1.53^{\circ}\text{C}$ , and  $1.19^{\circ}\text{C}$ , respectively. Between the 50 and 100 m levels, the differences do not exceed  $0.57^{\circ}\text{C}$ . Below 125 m, to 2000 m, the differences do not exceed  $0.07^{\circ}\text{C}$ .

The October-to-December temperature envelope taken from the statistical summaries was based on a sample size of six observations (Figure 3-4). The GDEM value at the surface does not fall within the envelope of observed values and differs from the typical by  $0.74^{\circ}\text{C}$ . Differences on the order of  $0.70^{\circ}\text{C}$  occur from the surface to 30 m. With the exception of a value of  $0.47^{\circ}\text{C}$  at 75 m, differences between 100 and 600 m do not exceed  $0.28^{\circ}\text{C}$ . Below 600 m, the differences do not exceed  $0.15^{\circ}\text{C}$ .

- Salinity:

The January-to-March salinity envelope taken from the statistical summaries was based on a sample size of 86 observations (Figure 3-5). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.12 ppt. Differences below the surface from 10 m down to 1000 m are less than 0.16 ppt. Below 1000 m, the differences do not exceed 0.09 ppt.

The April-to-June salinity envelope taken from the statistical summaries was based on a data sample size of nine observations (Figure 3-6). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.9 ppt. Differences between 10 and 75 m do not exceed 0.12 ppt. Below 125 m, the differences do not exceed 0.09 ppt.

The July-to-September salinity envelope taken from the statistical summaries was based on a data sample size of 21 observations (Figure 3-7). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.18 ppt. Differences below the surface between 10 and 30 m and 200 to 1000 m range from 0.11 to 0.15 ppt. Below 1000 m, the differences do not exceed 0.09 ppt.

The October-to-December salinity envelope taken from the statistical summaries was based on a data sample size of six observations (Figure 3-8). The GDEM value at the surface falls within the envelope of observed values and differs from the typical by only 0.07 ppt. Differences below 10 m to 2000 m do not exceed 0.08 ppt.

- Sound Speed:

The January-to-March sound-speed envelope taken from the statistical summaries was based on a sample size of 86 observations (Figure 3-9). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.3 m/s. With the exception of a difference of 0.6 m/s at 100 m, all differences below the surface down to 2000 m do not exceed 0.4 m/s.

The April-to-June sound-speed envelope taken from the statistical summaries was based on a sample size of nine observations (Figure 3-10). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by 3.3 m/s. With the exception of 1.6 m/s, 1.4 m/s, 1.1 m/s, 1.0 m/s, and 0.8 m/s at the 10 m, 50 m, 75 m, 100 m, and 125 m levels, respectively, all differences below the surface down to 2000 m do not exceed 0.5 m/s.

The July-to-September sound-speed envelope taken from the statistical summaries was based on a sample size of 21 observations (Figure 3-11). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by 3.0 m/s. Differences in value below the surface and down to 100 m range between 0.8 m/s and 4.0 m/s. Differences below 125 m down to 2000 m do not exceed 0.3 m/s.

The October-to-December sound-speed envelope taken from the statistical summaries was based on a data sample of six observations (Figure 3-12). The GDEM value at the surface falls outside of the envelope of observed values and differs from the typical by 2.3 m/s. Differences in value below the surface and down to 75 m range between 1.2 and 2.3 m/s. Differences below 150 m down to 2000 m do not exceed 0.8 m/s.

### 3.3 Evaluation - Balearic Sea (Location #2)

- January to March:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in the thermal structures. Differences in the absolute numerical values are quite small from the surface down to 2000 m. The GDEM profile is nearly identical to the typical. The GDEM profile remains within the entire envelope of observed values. GDEM appears to reflect a predominant and reasonable seasonally averaged winter thermal structure for this highly variable ocean region when compared with the 86 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals similarities in the haline structures. Above 200 m, the envelope of variability is quite wide (approximately 0.70 ppt). Below 200 m, the envelope narrows progressively with depth. The GDEM profile remains within the envelope and closely resembles the typical above 400 m. Below 400 m, the GDEM profile falls outside the envelope of observed values, being slightly low by approximately 0.08 ppt. The numerical value of the GDEM salinity below 400 m can perhaps be increased by approximately 0.08 to 1.20 ppt. With the exception of the lower numerical values of salinity below 400 m, the general GDEM salinity profile appears to reflect a predominant and reasonable seasonally averaged winter haline structure for this highly variable ocean region when compared with the 86 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals similarities throughout the entire vertical range of depths. The absolute numerical differences are very small. The proper half-channel mode is firmly represented. The GDEM sound-speed profile remains within the envelope of observed values. GDEM appears to reflect a predominant and reasonable seasonally averaged winter sound-speed structure for this highly variable ocean region when compared with the 86 usable observations.

- April to June:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in the thermal structures. The differences in the absolute numerical values are quite small from the surface down to 2000 m. The GDEM surface value differs from the typical but is realistically acceptable. With the exception of the 150 m level, the GDEM temperature profile remains within the entire envelope of observed values. Below 200 m, this region is quite stable during this time period and is adequately represented by the tightness of fit of the envelope and profiles. GDEM appears to reflect a predominant and reasonable seasonally averaged spring thermal structure for this highly variable region when compared with the nine usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals similarities in the upper portion (above 100 m) of the halocline. The gradients between 100 to 200 m indicate that GDEM has a stronger salinity gradient. Above 500 m, the salinity profile of GDEM is representative. Below 500, GDEM falls outside of the narrow envelope by a small amount (0.04 ppt). GDEM profile below 150 m can be increased by perhaps 0.11 ppt down to 2000 m. GDEM appears to reflect a predominant and reasonable seasonally averaged spring salinity structure for this highly variable region when compared with the nine usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals similarities over much of the vertical column. The GDEM reflects and remains within a very tight spring envelope. The primary sound-channel axis is developing at a reasonable depth range for this region and is similar to the typical. The curvature above the apex of the sound-channel axis is slightly less in GDEM than in the typical. A cause for that difference can be seen by the characteristics of the temperature and salinity profiles at those depths. This difference appears to be a realistic variability, as indicated by the sudden broadening of the envelope at those depths. GDEM appears to reflect an acceptable seasonally averaged spring sound-speed structure for this highly variable region when compared with the nine usable observations.

- July to September:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in the thermal structures. The thermocline gradients and absolute numerical values of the profiles are very similar. GDEM remains properly within the very narrow envelope below 150 m. The envelope of observed values is substantially wide for GDEM spring structuring and reflects a zone of



sufficient thermal variability. GDEM appears to reflect a predominant and reasonable seasonally averaged summer thermal structure for this highly variable ocean region when compared with the 21 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals general similarities in the haline structures. Although remaining within the envelope of observed values, there is a noticeable difference in the gradient of the halocline between 125 to 200 m. This difference strongly influences the remaining portion of the GDEM salinity profile to fall and remain outside of the envelope. The difference between the GDEM values and envelope below 400 m is slight and remains at approximately 0.6 ppt. The spread in the width of the envelope above 150 m is modest and suggests that the salinity variability for this region is modest during the summer. An increase of between 0.08 and 0.12 ppt can be made to GDEM levels below 150 m. GDEM appears to reflect a predominant and reasonable seasonally averaged summer haline structure for this highly variable ocean region when compared with the 21 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals similarities in the near surface as well as below the sound-channel axis. The sonocline gradients are very similar though differing in numerical value. There appears to be a difference in the depths of the subsurface minimas of approximately 25 m and a difference in numerical values between the minimas of only 0.6 m/s. The depth of the GDEM minima appears to remain reasonable and within the envelope of observed values. The difference in depths of subsurface minimas appears to be caused by temperature structure differences at those depths. GDEM appears to reflect a reasonable seasonally averaged summer sound-speed structure for this highly variable ocean region when compared with the 21 usable observations.

- October to December:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in gradients and thermal structure, but differences in numerical values throughout the vertical profile. The differences are maximum in the near-surface layers (less than  $0.7^{\circ}\text{C}$ ) and decrease to less than  $0.05^{\circ}\text{C}$  below 1000 m. The GDEM profile persistently remains outside the envelope of observed values (only six observations). The displacement of the GDEM profile outside the narrow envelope is not considered incorrect.

Data sampling appears to be a direct causal factor in the GDEM profile existing outside the envelope. GDEM appears to reflect the general trend of the gradients and features of the typical and envelope of observed data for this highly variable ocean region when compared with the six usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals similarities in the haline structures. An increase in salinity of between 0.08 and 0.12 ppt can be made to GDEM levels below 150 m. GDEM appears to reflect the overall general trend as well as a smooth seasonally averaged historical profile for the fall haline structure for this highly variable region when compared with the six usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals similarities in gradient and structure, but differences in numerical value throughout the vertical profile. The GDEM profile persistently remains outside the envelope of observed values (only six observations). The displacement of the GDEM profile outside the envelope appears to be directly related to the characteristics of the temperature profile. As stated in the temperature evaluation, this displacement is not necessarily incorrect, but may be caused by biased data sampling. The general GDEM trend is similar, and the characteristic of the GDEM sound-channel axis is not as abrupt at 75 m as the typical. The general trend and smooth seasonally averaged historical profile of GDEM for the fall sound-speed structure for this highly variable ocean region is considered representative.

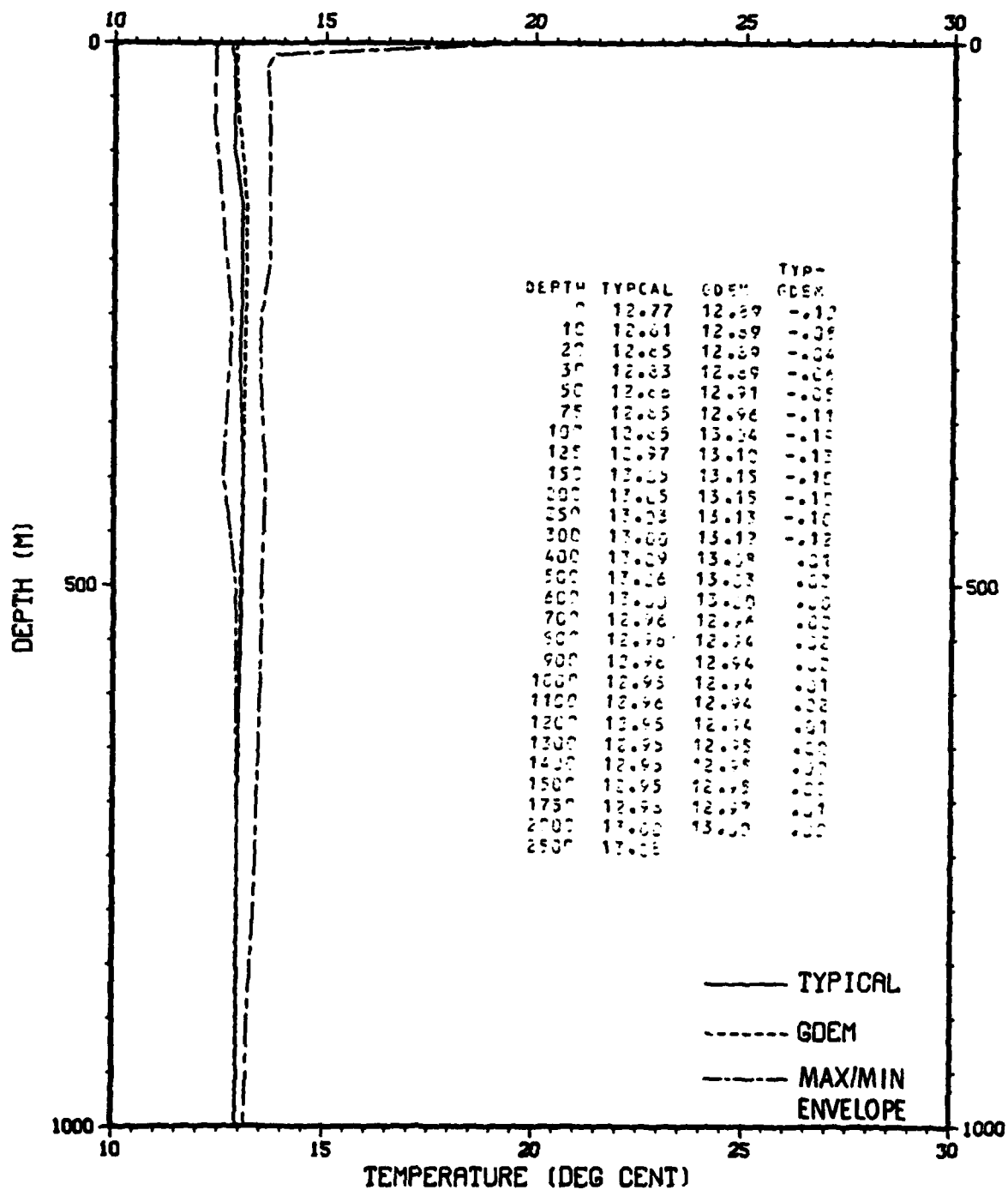


FIG. 3-1. VERTICAL TEMPERATURE PROFILE FOR BALEARIC SEA (JAN - MAR)

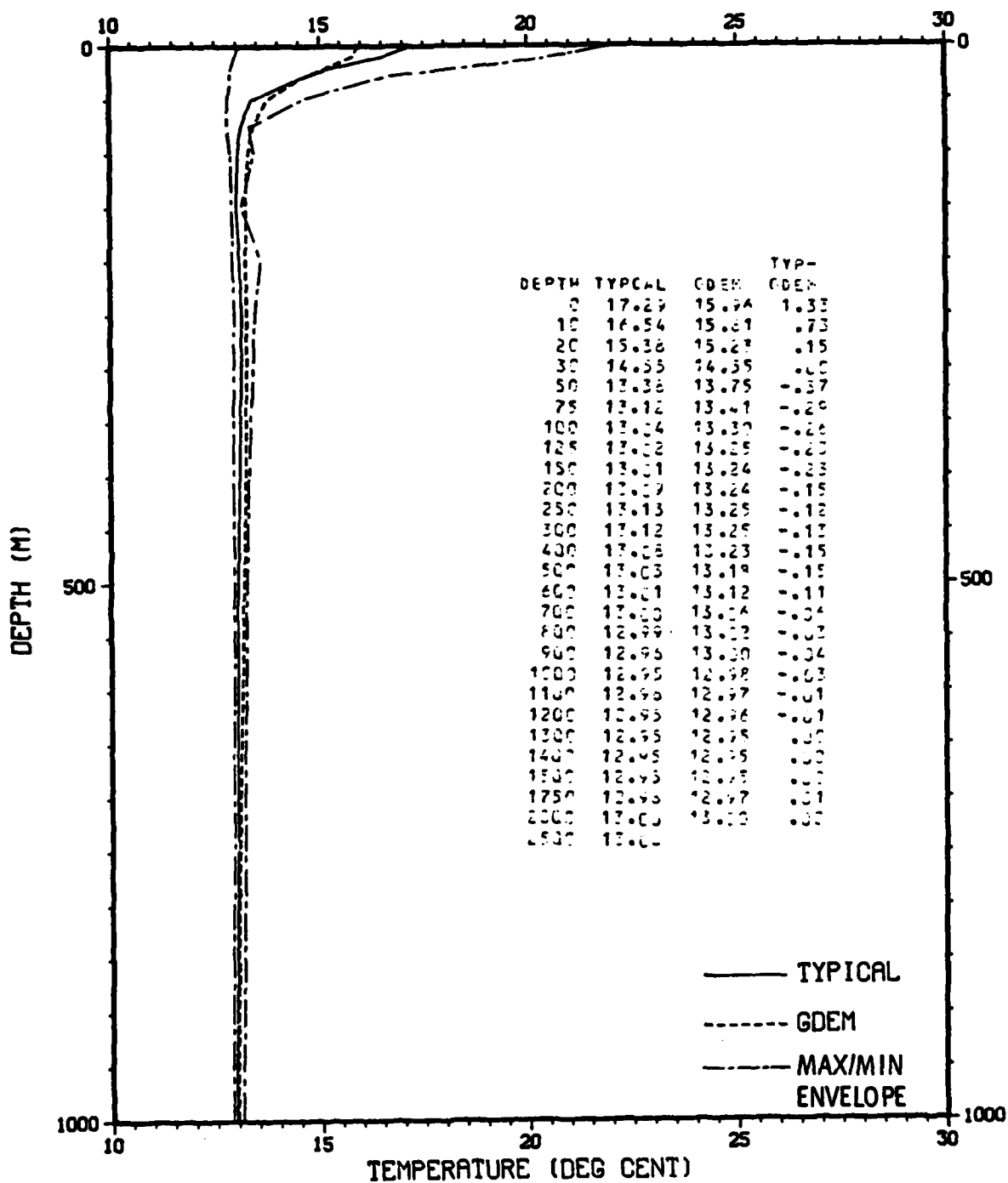


FIG. 3-2. VERTICAL TEMPERATURE PROFILE FOR BALEARIC SEA (APR - JUN)

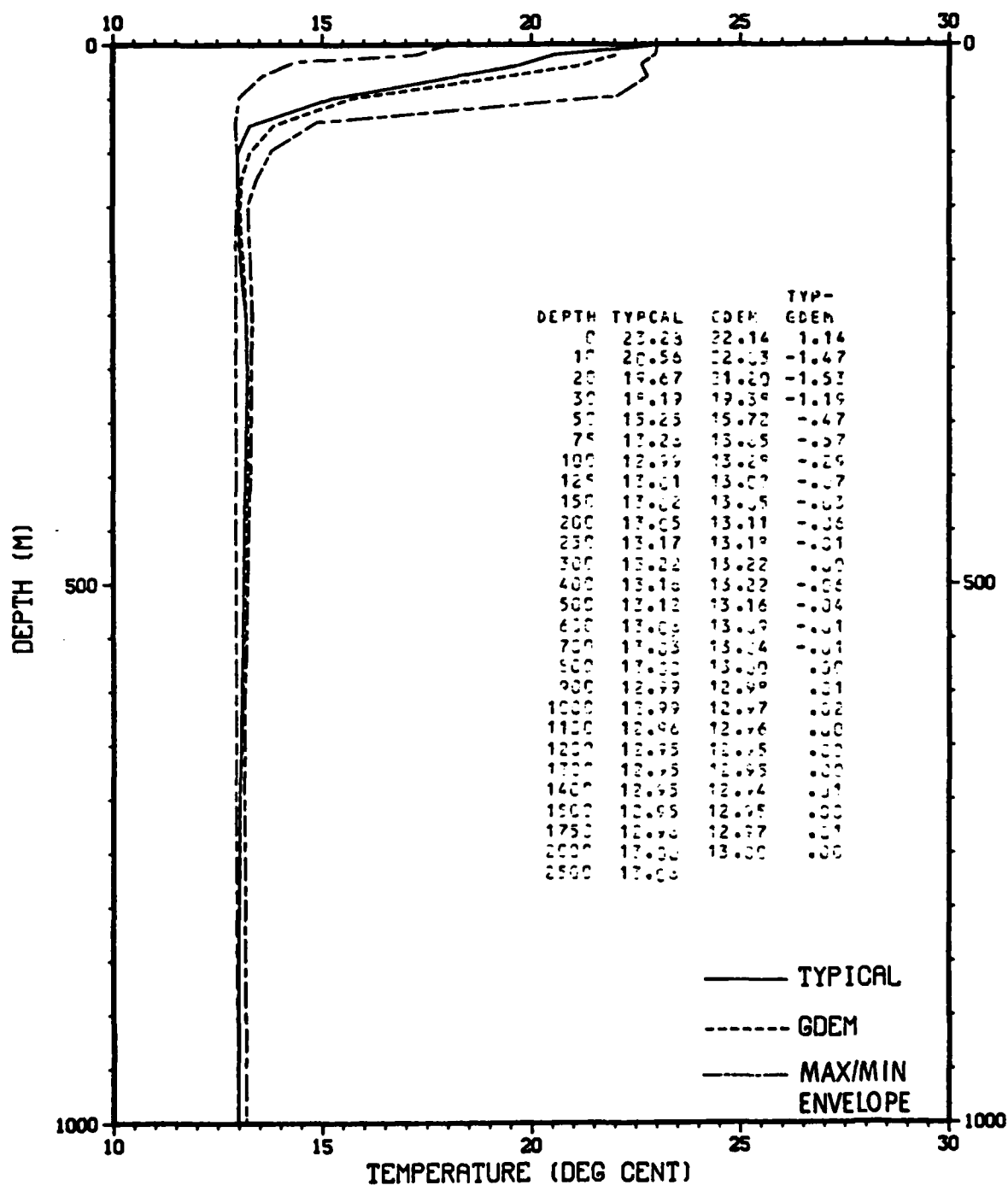


FIG. 3-3. VERTICAL TEMPERATURE PROFILE FOR BALEARIC SEA (JUL - SEP)

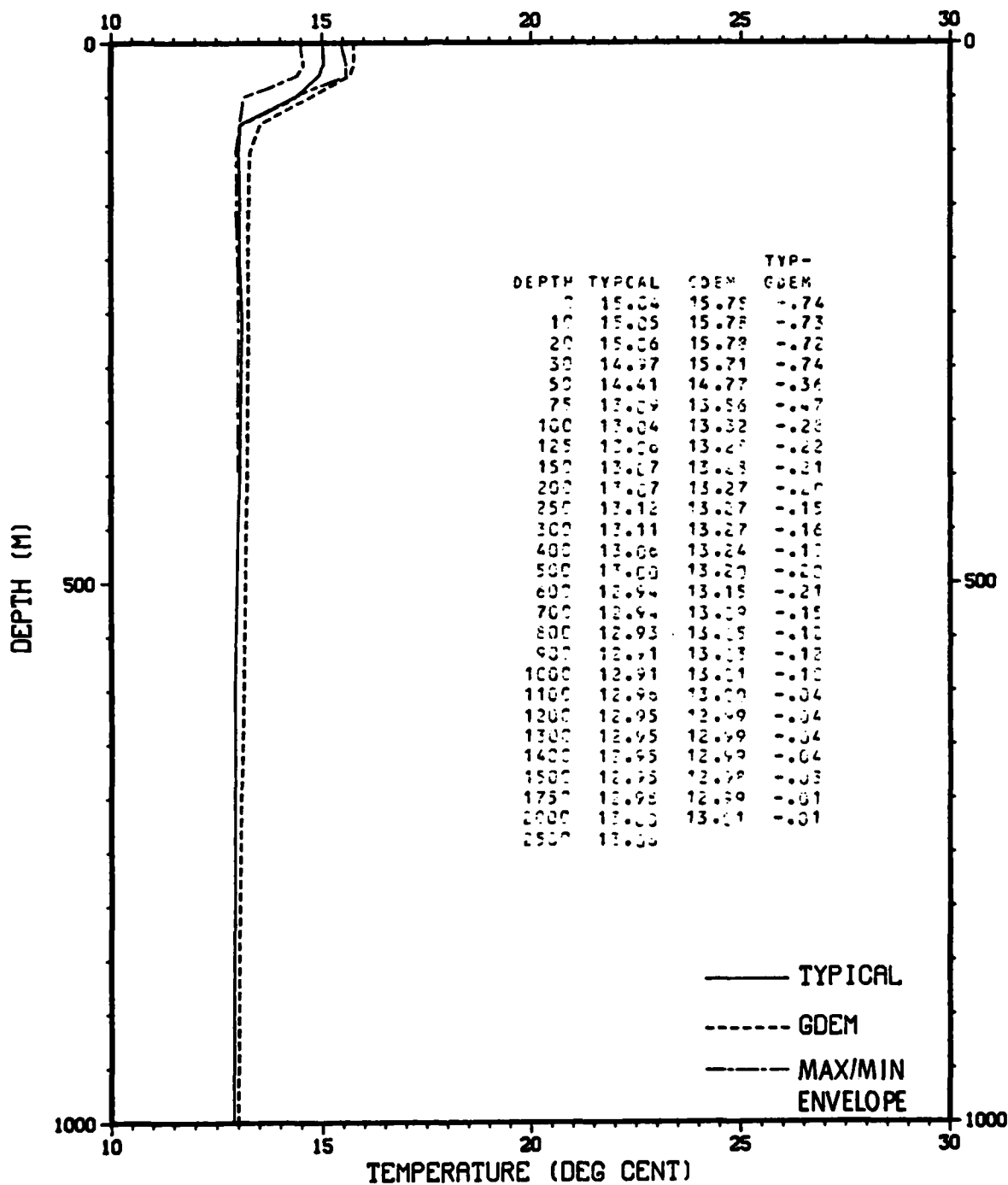


FIG. 3-4. VERTICAL TEMPERATURE PROFILE FOR BALEARIC SEA (OCT - DEC)

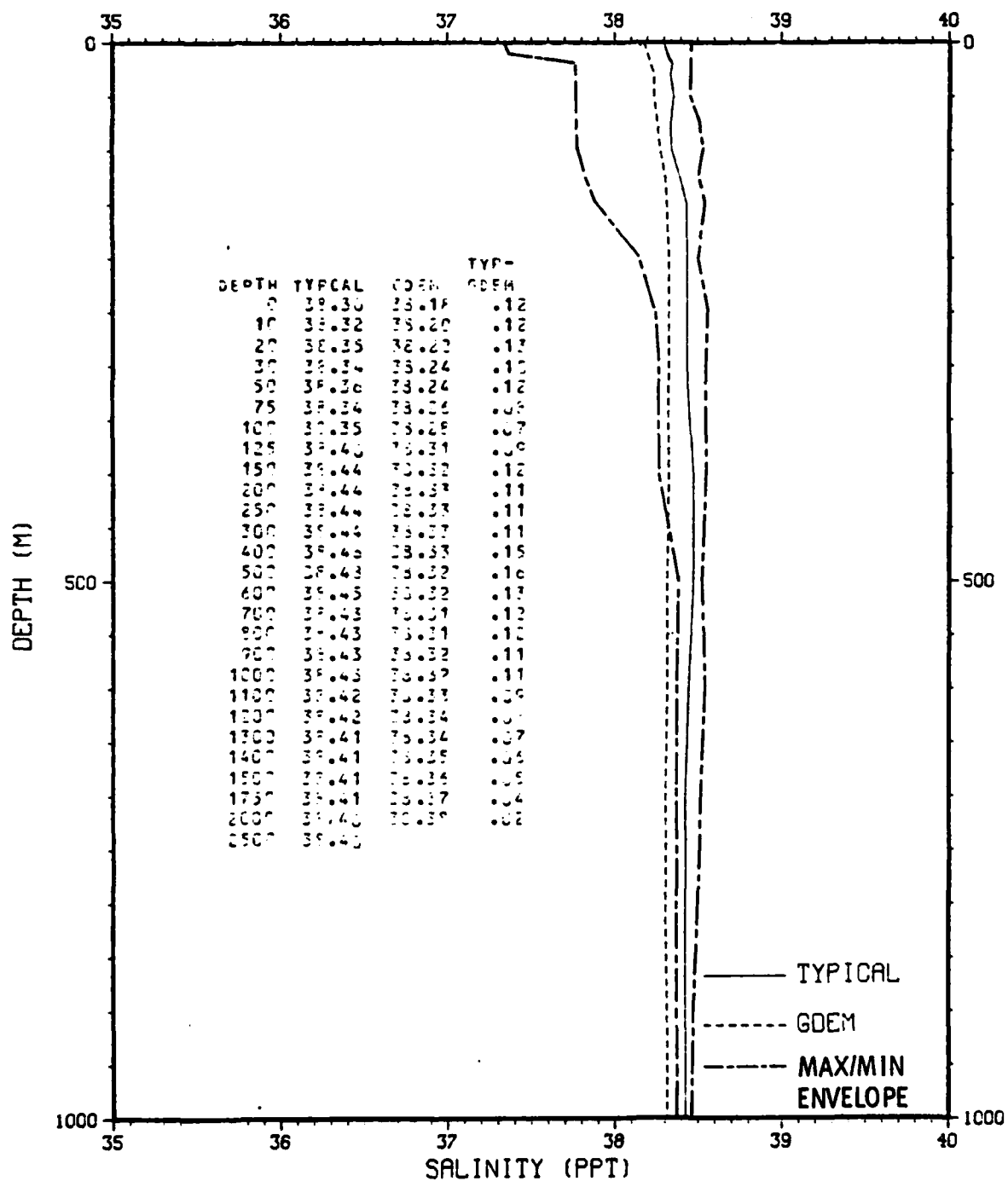


FIG. 3-5. VERTICAL SALINITY PROFILE FOR BALEARIC SEA (JAN - MAR)

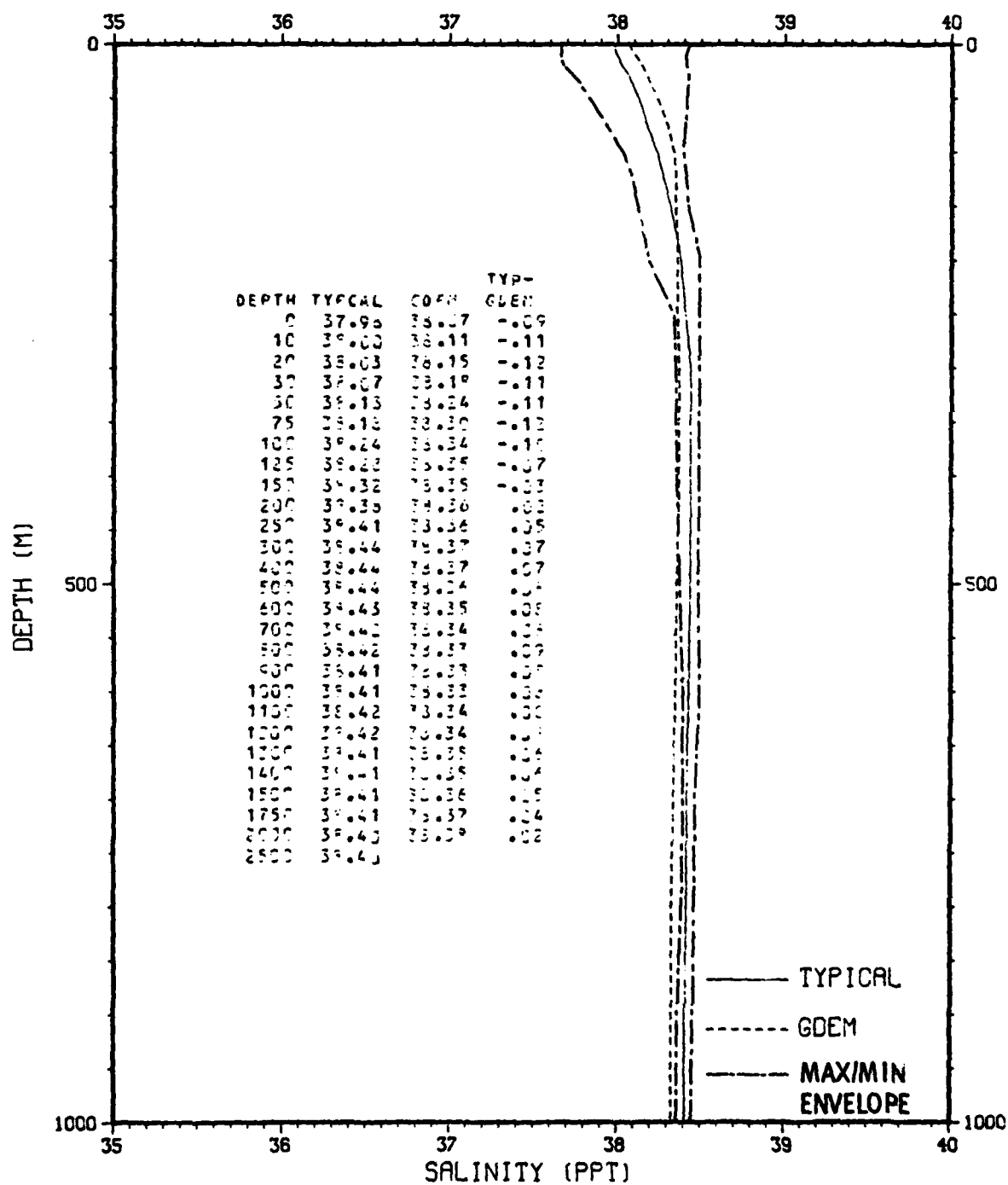


FIG. 3-6. VERTICAL SALINITY PROFILE FOR BALEARIC SEA (APR - JUN)



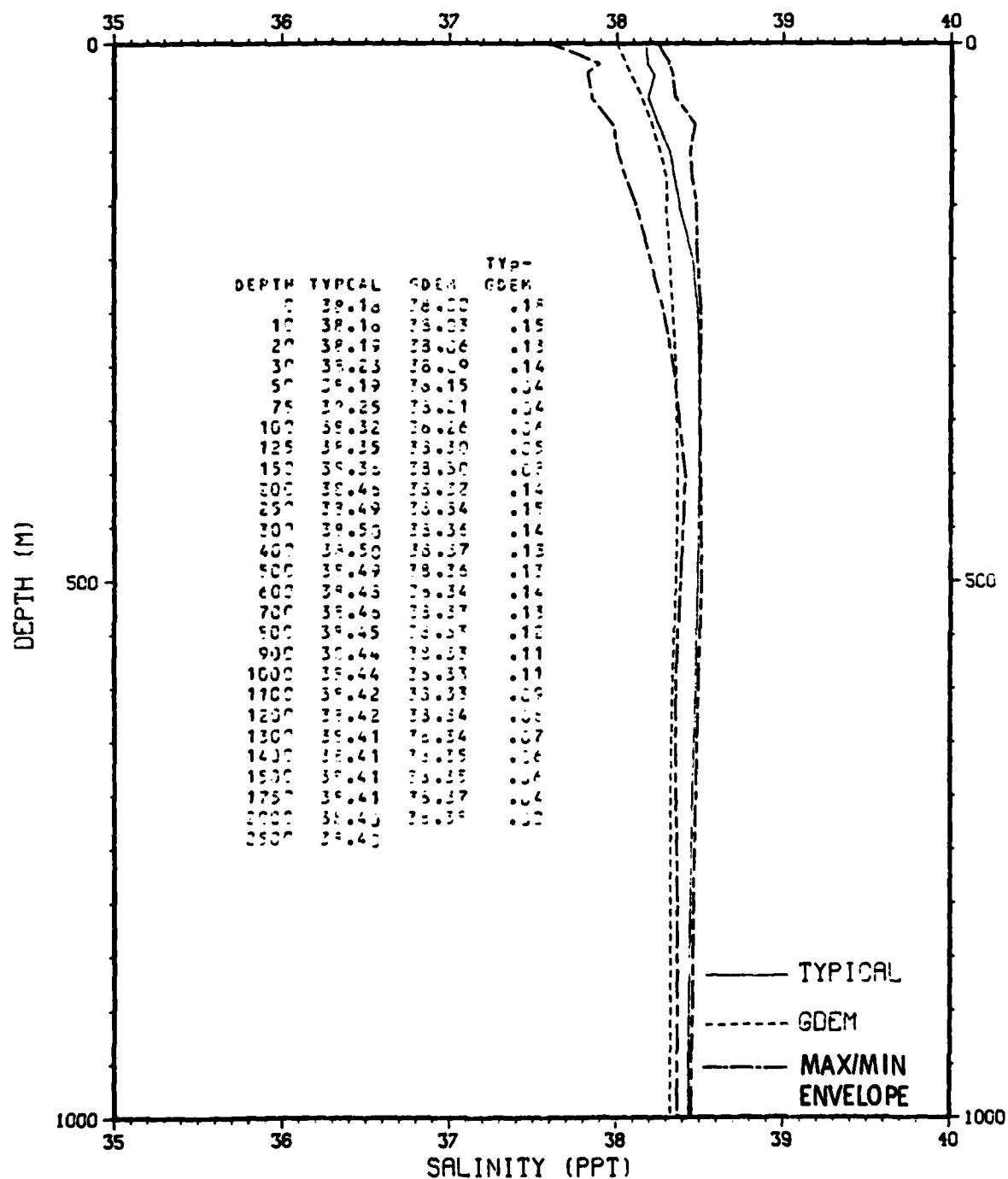


FIG. 3-7. VERTICAL SALINITY PROFILE FOR BALEARIC SEA (JUL - SEP)

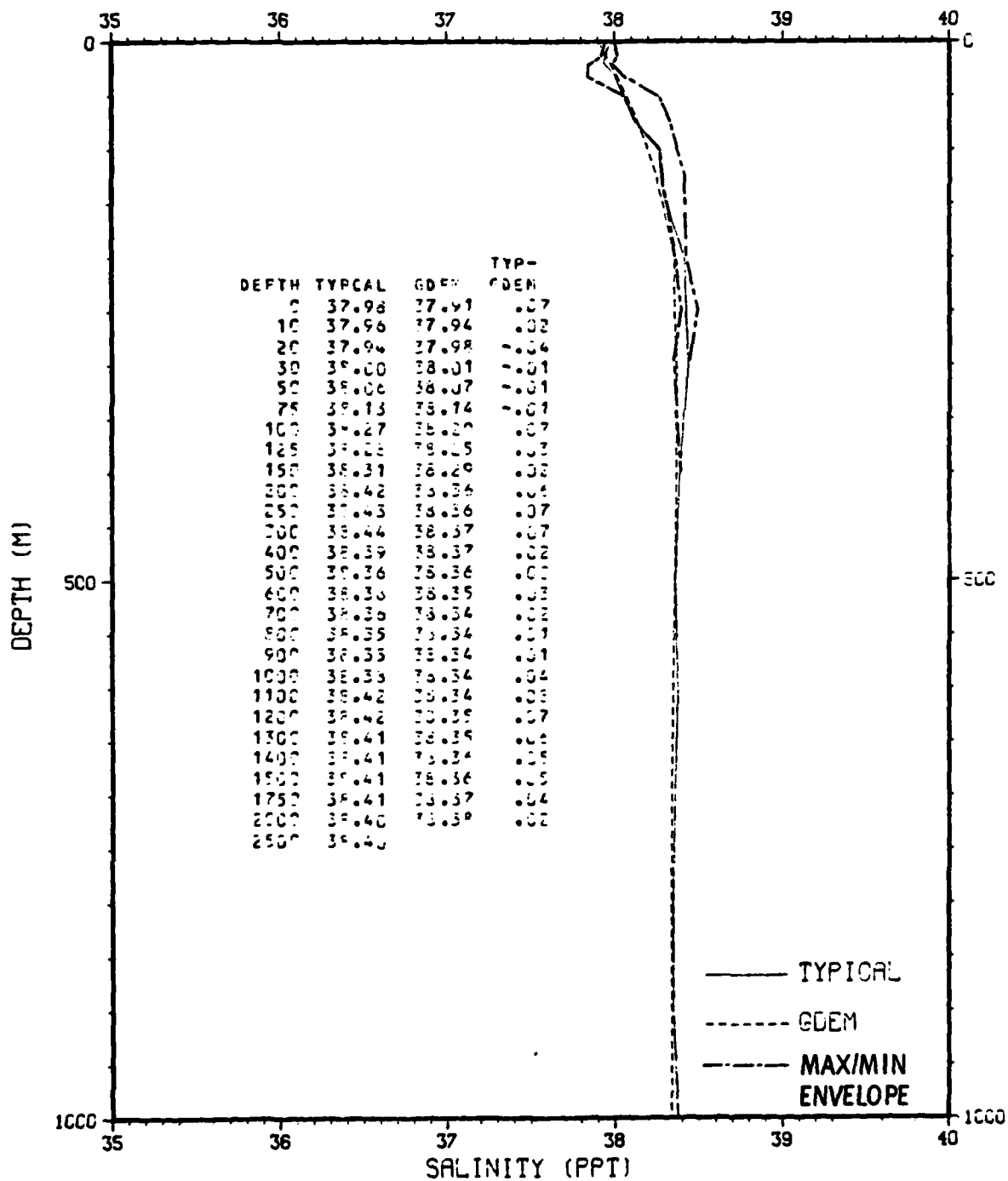


FIG. 3-8. VERTICAL SALINITY PROFILE FOR BALEARIC SEA (OCT - DEC)

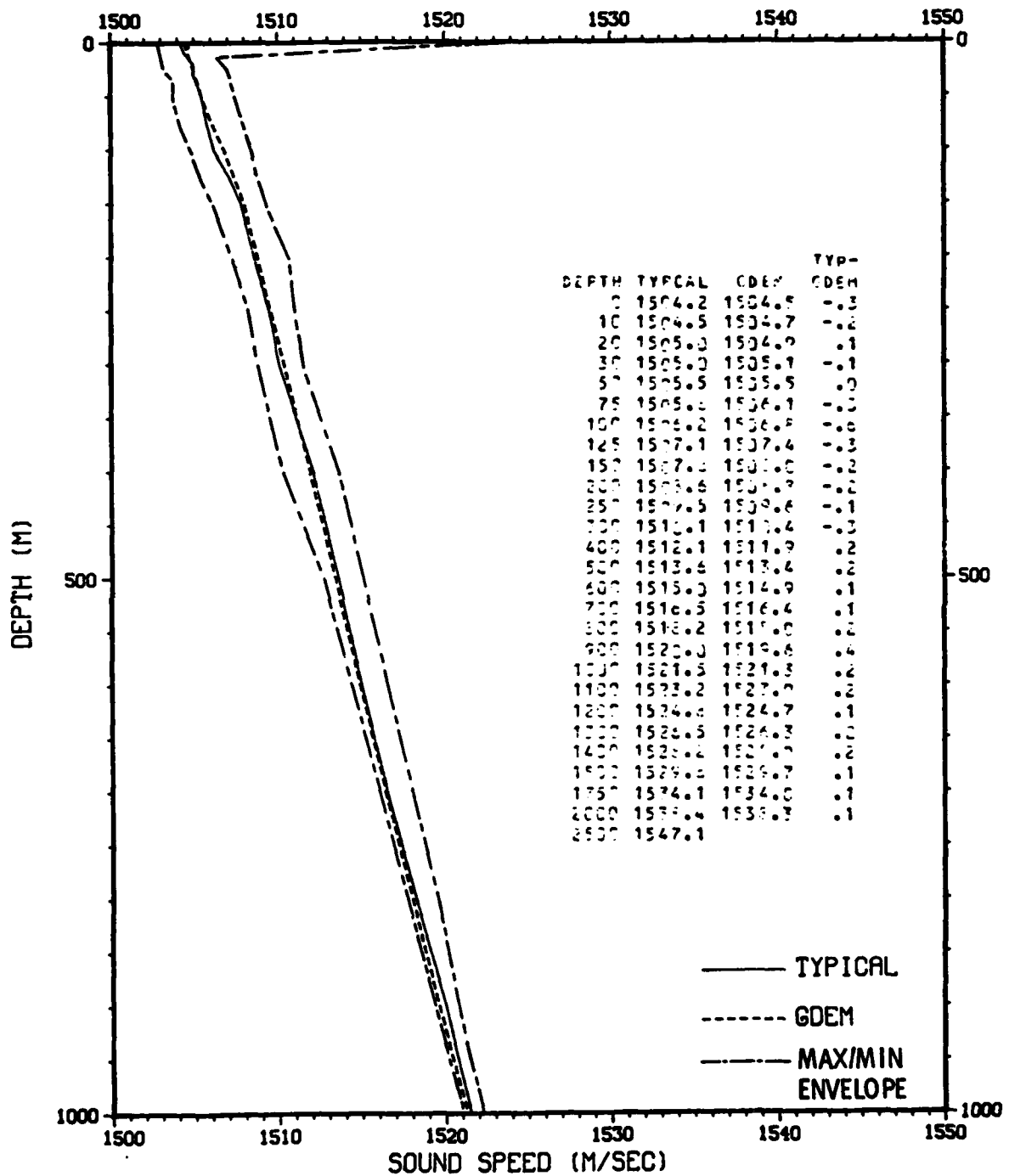


FIG. 3-9. VERTICAL SOUND-SPEED PROFILE FOR BALEARIC SEA (JAN - MAR)

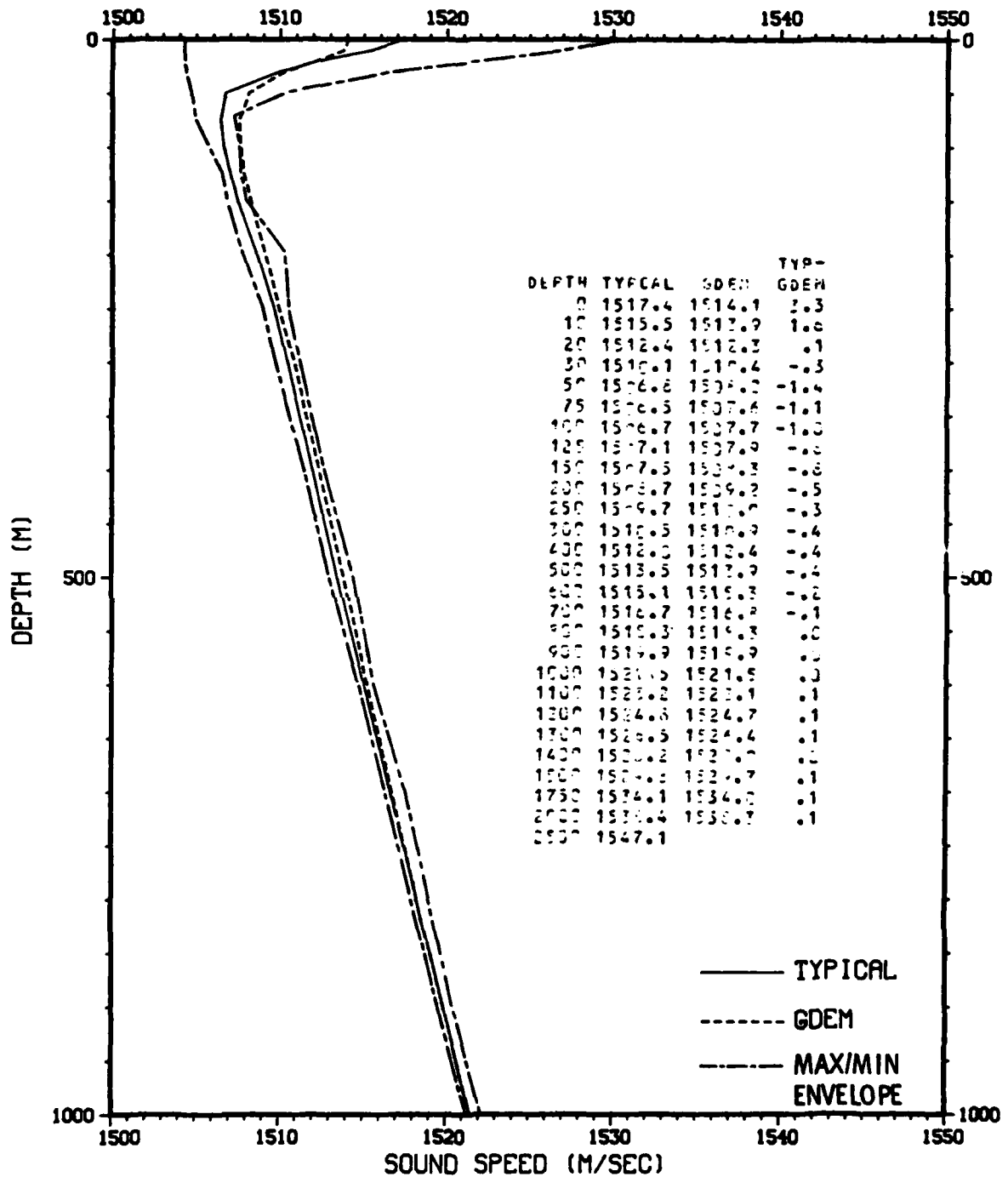


FIG. 3-10. VERTICAL SOUND-SPEED PROFILE FOR BALEARIC SEA (APR - JUN)

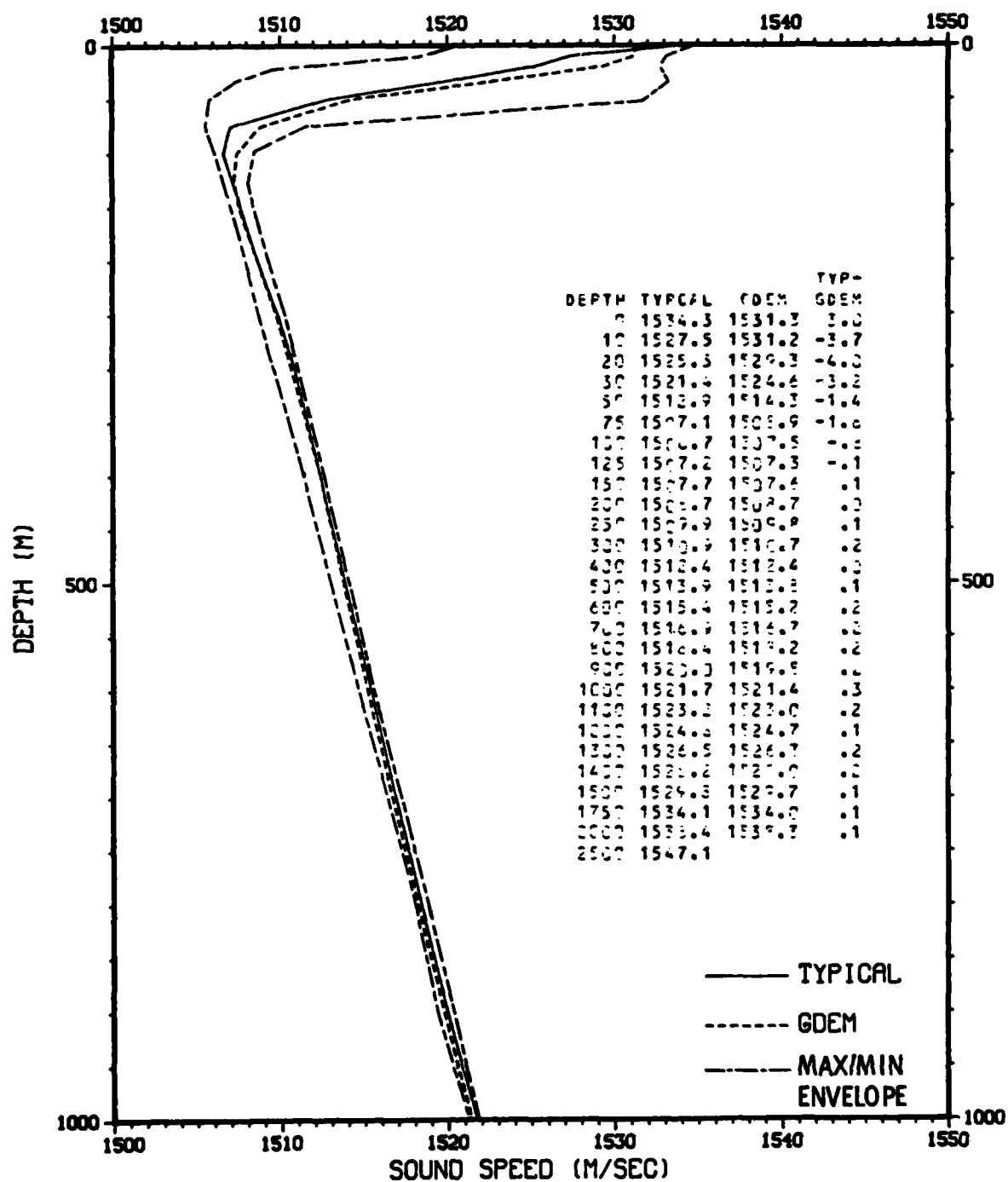


FIG. 3-11. VERTICAL SOUND-SPEED PROFILE FOR BALEARIC SEA (JUL - SEP)

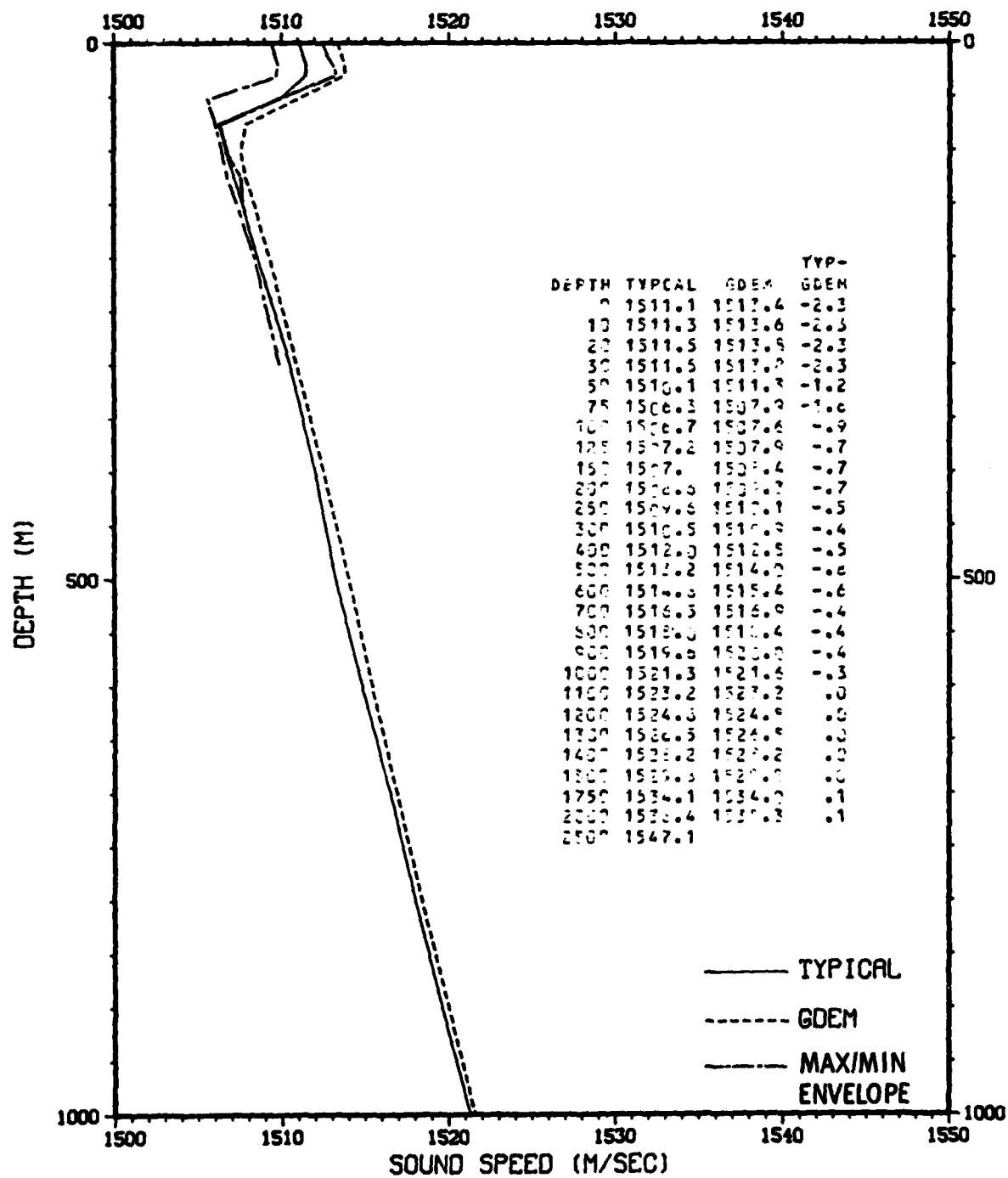


FIG. 3-12. VERTICAL SOUND-SPEED PROFILE FOR BALEARIC SEA (OCT - DEC)

#### 4.0 VERTICAL TEMPERATURE, SALINITY, AND SOUND-SPEED PROFILE COMPARISONS FOR MEDITERRANEAN (MED) LOCATION #3

Twelve vertical comparisons of temperature (T), salinity (S), and sound-speed (SS) for winter, spring, summer, and fall seasons are presented in this section.

##### 4.1 Description

Med Location #3 is taken from the Tyrrhenian Sea region of the Mediterranean Sea. The geographical location selected for this comparison is at  $40^{\circ}00'$  north latitude and  $012^{\circ}00'$  east longitude. Vertical temperature, salinity, and sound-speed profiles of seasonal comparisons are shown in Figures 4-1 through 4-12.

The Tyrrhenian Sea region of the central Mediterranean Sea, depicted as Region C in Figure 1-1, is defined for this report as the body of water bounded to the west by the islands of Corsica and Sardinia; to the north and east by the southern coastline of Italy, and to the south by the island of Sicily.

Meteorologically, this region is considered variable and influenced in part by a region of cyclogenesis located over the Gulf of Genoa. The major geographical feature influencing the role of cyclogenesis in the Gulf of Genoa is the Alps, which are north of Italy. The Alps have been known to play a key role in determining the weather over the Gulf of Genoa, the northern Adriatic Sea, and the Ligurian Sea in terms of fronts, planetary waves, and degree of cyclogenesis. The Gulf of Genoa is perhaps one of the most significant regions of the world for cyclogenesis.

Oceanographically, this region is considered variable. The ocean variability and changes in the vertical water column (more so than in the horizontal) are directly influenced by the impulses received from the path of cyclogenesis which begin in the Gulf of Genoa toward the eastern part of Sicily. The vertical variability throughout the track region can be expected to provide broad and relatively deep seasonal ocean variability.

#### 4.2 Comparisons for Location #3

The vertical site comparisons of seasonal temperature, salinity, and sound-speed profiles, respectively, are presented for Med Location #3.

- Temperature:

The January-to-March temperature envelope taken from the statistical summaries was based on a sample size of 15 observations (Figure 4-1). The GDEM value at the surface falls well within the envelope of observed values. There is no difference between the numerical values at the surface. Between the 10 and 300 m levels, differences are less than  $0.09^{\circ}\text{C}$ . Between the 400 and 900 m levels, differences do not exceed  $0.21^{\circ}\text{C}$ . Below 900 m, the differences do not exceed  $0.06^{\circ}\text{C}$ .

The April-to-June temperature envelope taken from the statistical summaries was based on a sample size of 11 observations (Figure 4-2). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by  $1.46^{\circ}\text{C}$ . Differences at the 10 m, 20 m, and 30 m levels are  $1.77^{\circ}\text{C}$ ,  $1.46^{\circ}\text{C}$ , and  $1.08^{\circ}\text{C}$ , respectively. Between 75 m and 1000 m, the differences do not exceed  $0.33^{\circ}\text{C}$ . Below 1000 m, the differences do not exceed  $0.07^{\circ}\text{C}$ .

The July-to-September temperature envelope taken from the statistical summaries was based on a sample size of 40 observations (Figure 4-3). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by  $0.30^{\circ}\text{C}$ . Differences at the 30 m and 50 m levels are  $2.69^{\circ}\text{C}$  and  $1.12^{\circ}\text{C}$ , respectively. Between the 75 m and 1000 m levels, the differences do not exceed  $0.32^{\circ}\text{C}$ . Below 1000 m, the differences do not exceed  $0.06^{\circ}\text{C}$ .

The October-to-December temperature envelope could not be developed from the statistical summaries because of an insufficient number of adequate data samples (Figure 4-4). There were only two usable observations for this location. The GDEM value at the surface differs from the only available typical by  $2.92^{\circ}\text{C}$ . This magnitude of difference continues at the 10 m, 20 m, and 30 m levels. Between the 75 m and 400 m levels, the differences do not exceed  $0.38^{\circ}\text{C}$ . Below 400 m, the differences do not exceed  $0.16^{\circ}\text{C}$ .

- Salinity:

The January-to-March salinity envelope taken from the statistical summaries was based on a data sample size of 15 observations



(Figure 4-5). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by 0.11 ppt. Various differences in numerical value are found between the profiles with depth. Between the 10 and 30 m levels, the differences are less than 0.05 ppt. Between 50 and 100 m, the differences range from 0.12 to 0.18 ppt. Between 125 and 2000 m, the differences do not exceed 0.12 ppt.

The April-to-June salinity envelope taken from the statistical summaries was based on a data sample size of 11 observations (Figure 4-6). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.02 ppt. Between the 10 and 1300 m levels, the differences do not exceed 0.12 ppt. Below 1750 m, the differences do not exceed 0.06 ppt.

The July-to-September salinity envelope taken from the statistical summaries was based on a data sample size of 40 observations (Figure 4-7). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.06 ppt. Differences of 0.26 and 0.21 ppt exist at the 50 and 75 m levels, respectively. Below 200 m down to 1400 m, the differences are between 0.08 and 0.13 ppt. Below 1750 m, the differences do not exceed 0.06 ppt.

The October-to-December salinity envelope could not be developed from the statistical summaries because of an insufficient number of adequate data samples (Figure 4-8). There were only two usable observations for this location. The GDEM value at the surface differs from the nonrepresentative typical by 0.27 ppt. A maximum difference of 0.33 ppt exists at 50 m. Between 100 and 1400 m, the differences do not exceed 0.13 ppt. Below 1750 m, the differences do not exceed 0.06 ppt.

- Sound Speed:

The January-to-March sound-speed envelope taken from the statistical summaries was based on a data sample size of 15 observations (Figure 4-9). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.1 m/s. With the exception of the differences at the 400 m, 500 m, and 600 m levels (which have differences of only 0.4 m/s, 0.6 m/s, and 0.4 m/s, respectively), all differences below the surface and down to 3000 m do not exceed 0.3 m/s.

The April-to-June sound-speed envelope, taken from the statistical summaries was based on a data sample size of 11 observations (Figure 4-10). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by

4.6 m/s. Differences of 5.5 m/s, 4.6 m/s, 3.5 m/s, 1.9 m/s, 1.2 m/s, and 1.0 m/s exist at the 10 m, 20 m, 30 m, 50 m, 75 m, and 100 m levels, respectively. Below 100 m and down to 3000 m, all differences do not exceed 0.7 m/s.

The July-to-September sound-speed envelope taken from the statistical summaries was based on a sample size of 40 observations (Figure 4-11). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.7 m/s. With the exception of the differences at the 20 m, 30 m, 50 m, 250 m, 300 m levels (which have differences of 2.2 m/s, 6.9 m/s, 3.2 m/s, 0.8 m/s, and 1.1 m/s, respectively) all differences below the surface down to 3000 m do not exceed 0.7 m/s.

The October-to-December sound-speed envelope could not be developed from the statistical summaries because of an insufficient number of adequate data samples (Figure 4-12). There were only two usable observations for this location. The GDEM value at the surface differs from the nonrepresentative typical by 7.4 m/s. Differences below the surface down to 100 m do exist. These differences for the 10 m, 20 m, 30 m, 50 m, 75 m, and 100 m levels are 8.3 m/s, 7.6 m/s, 8.0 m/s, 3.0 m/s, 1.5 m/s, and 1.3 m/s, respectively. With the exception of the 125 and 250 m levels, all differences below 125 m down to 3000 m do not exceed 0.5 m/s.

#### 4.3 Evaluation - Tyrrhenian Sea (Location #3)

- January to March:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in the thermal structures. The differences in the absolute numerical values are quite small from the surface down to 3000 m. The GDEM profile is nearly identical to the typical. The GDEM profile remains within the entire narrow envelope of observed values. A relatively isothermal characteristic is known for this region. GDEM appears to reflect a predominant and reasonable seasonally averaged winter thermal structure for this variable region when compared with the 15 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals similarities in the general trend of numerical value and gradient. The GDEM historical profile reflects a late seasonally averaged winter profile. Both GDEM and the typical remain within the relatively broad envelope (approximately 0.4 ppt) between 100 and 200 m. GDEM appears to reflect an acceptable winter haline structure for this variable region when compared with the 15 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals very close similarities throughout the entire vertical range of depths. The differences in the numerical values are very small and the envelope of observed values is quite narrow and well defined. The proper half-channel mode is firmly represented. GDEM appears to reflect a predominant and reasonable seasonally averaged winter sound-speed structure for this variable ocean region when compared with the 15 usable observations.

- April to June:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities below 150 m. Between the surface and 150 m, the GDEM profile exhibits higher values and stronger thermal gradients within the thermocline region. Such temperatures and gradients are associated with biases caused by data sampling. The envelope in this section is wide, and suited for both types of thermal structures. Both GDEM and the typical remain within the envelope. GDEM appears to reflect an acceptable and reasonable seasonally averaged spring thermal structure for this variable ocean region when compared with the 11 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals similarities in gradient above 200 m. The numerical differences show GDEM as having higher values. The decreasing gradient of the GDEM halocline between 200 to 500 m contributes, in part, toward causing the profile to depart from the envelope. The salinity range for the region near 1000 m is well defined and known. The GDEM salinity values appear to be too low for the region below 500 m and can perhaps be increased by approximately 0.08 to 0.13 ppt. Following the slight adjustments below 500 m, GDEM appears to reflect an acceptable and reasonable seasonally averaged spring haline structure for this variable ocean region when compared with the 11 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals similarities below 150 m. Below the surface and down to 150 m, the GDEM is consistently higher in value. The sonocline gradient is also greater for GDEM; nevertheless, the GDEM profile remains within the envelope of observed values. The cause for the higher values in the GDEM sonocline results from contributions of higher values in temperature and salinity. The difference in gradient appears to be influenced more by the temperature profile. The envelope is substantially wide from the surface to the sound-channel axis. The depths of the sound-channel axes are quite similar in value. Both GDEM and the typical remain within the envelope. GDEM appears to reflect an acceptable and reasonable seasonally averaged spring sound-speed structure for this variable ocean region when compared with the 11 usable observations.

- July to September:

An evaluation of the GDEM and typical temperature profile comparison between the surface to 200 m and below 400 m down to 3000 m reveals similarities in thermal structure. Between 200 and 400 m, there is a noticeable difference between GDEM and the typical. GDEM between these levels indicates a nearly isothermal structure, whereas the typical indicates a slight secondary subsurface minimum at 300 m. Between 300 to 600 m, the GDEM profile falls slightly outside the envelope. The near surface thermal structure is very strong and well defined by realistic, representative, and known thermocline gradients for this region of the ocean. GDEM is considered representative of a seasonally averaged thermal structure for this variable ocean region when compared with the 40 usable observations.

An evaluation of the GDEM and typical salinity profile comparison exhibits a noticeable difference in profile characteristics as well as in numerical values. The envelope is very broad, especially near the surface, and remains noticeably wide with increased depth. In general, both the GDEM and the typical remain within the envelope. The haline structures of GDEM and the typical for the near-surface layers are a good example of a comparison between an average profile and an observed profile of salinity in a high-salinity, varying ocean environment. Both remain well within the broad envelope of observations. The GDEM structure exhibits trends and characteristics that are representative of a seasonally averaged salinity profile for this region of the ocean. The GDEM profile appears to reflect an acceptable and reasonable seasonally averaged haline structure for this variable ocean region when compared with the 40 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison between the surface to 200 m and below 400 m down to 3000 m reveals similarities in the sound-speed structure. The depths of the sound-channel axis are quite similar in numerical value. The GDEM structure appears to reflect a reasonable seasonally averaged summer sound-speed structure by GDEM for this variable ocean region when compared with the 40 usable observations.

- October to December:

An evaluation of the GDEM and typical temperature profile comparison reveals very close similarities in the thermal structures. The surface value is noticeably different, but the magnitude of the difference is realistic. The depths of the mixed layers are

similar, as well as the gradients of the thermoclines. The profiles below the bottom of the thermoclines are nearly identical. Due to an insufficient number of adequate data samples (two usable observations), an envelope was not developed. The GDEM appears to adequately reflect a reasonable seasonally averaged fall temperature structure for this variable ocean region.

An evaluation of the GDEM and typical salinity profile comparison reveals a reasonable seasonally averaged fall haline structure for this variable ocean region. Below 600 m, the gradient appears conservative with depth. The values below 500 m can perhaps be increased by approximately 0.05 ppt to 0.16 ppt. GDEM appears to reflect a reasonable seasonally averaged fall haline structure for this ocean region.

An evaluation of the GDEM and typical sound-speed profile comparison reveals similarities in the sound-speed structures. The surface layers are noticeably different in their numerical values; however, the depth of the sonic layer and the gradients of the sonocline are quite similar. The numerical values and gradients below the sound-channel axis and the approximate depths of the sound-channel axis are quite similar. GDEM appears to adequately represent a reasonable seasonally averaged fall sound-speed structure for this variable ocean region.

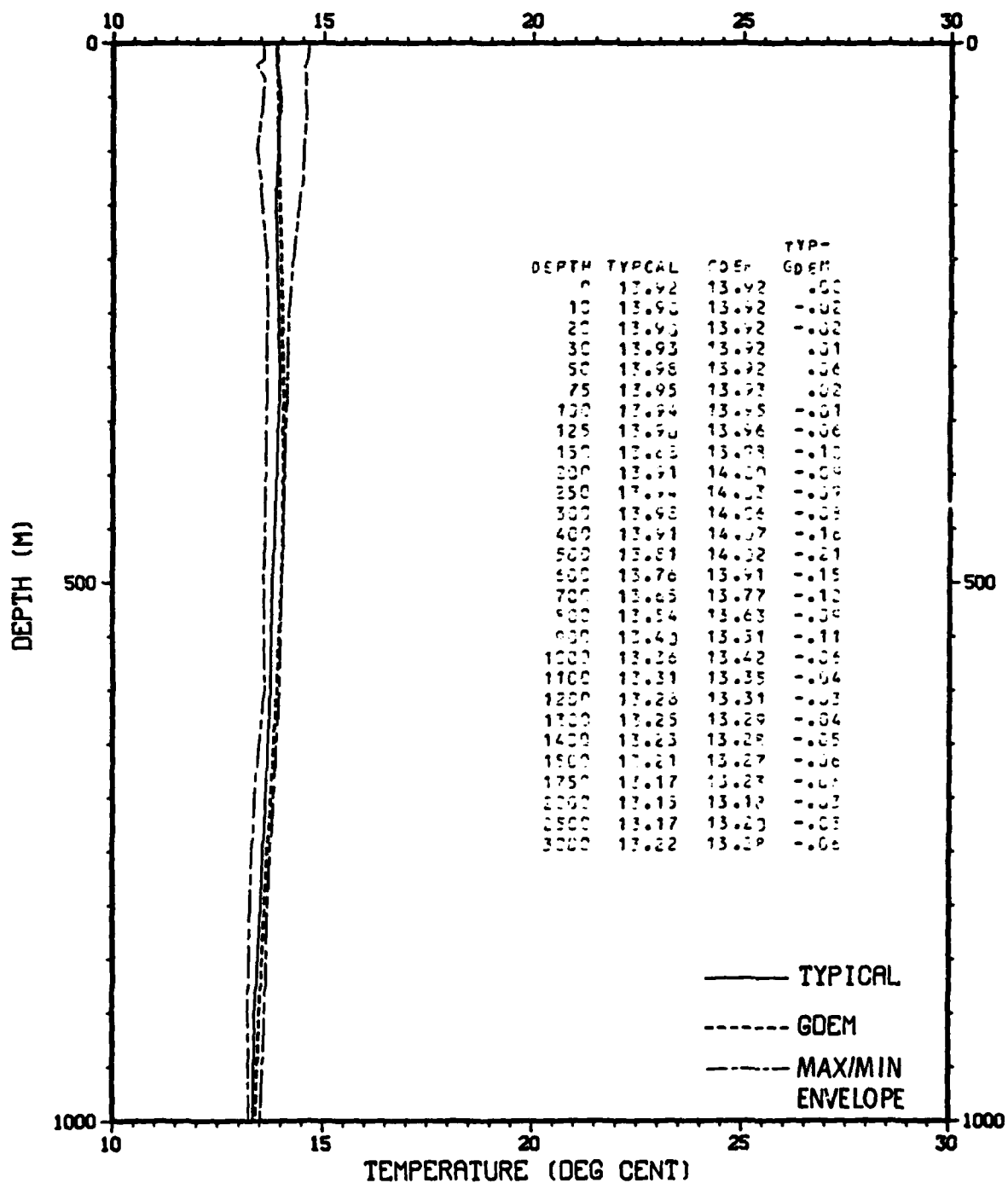


FIG. 4-1. VERTICAL TEMPERATURE PROFILE FOR TYRRHENIAN SEA (JAN - MAR)

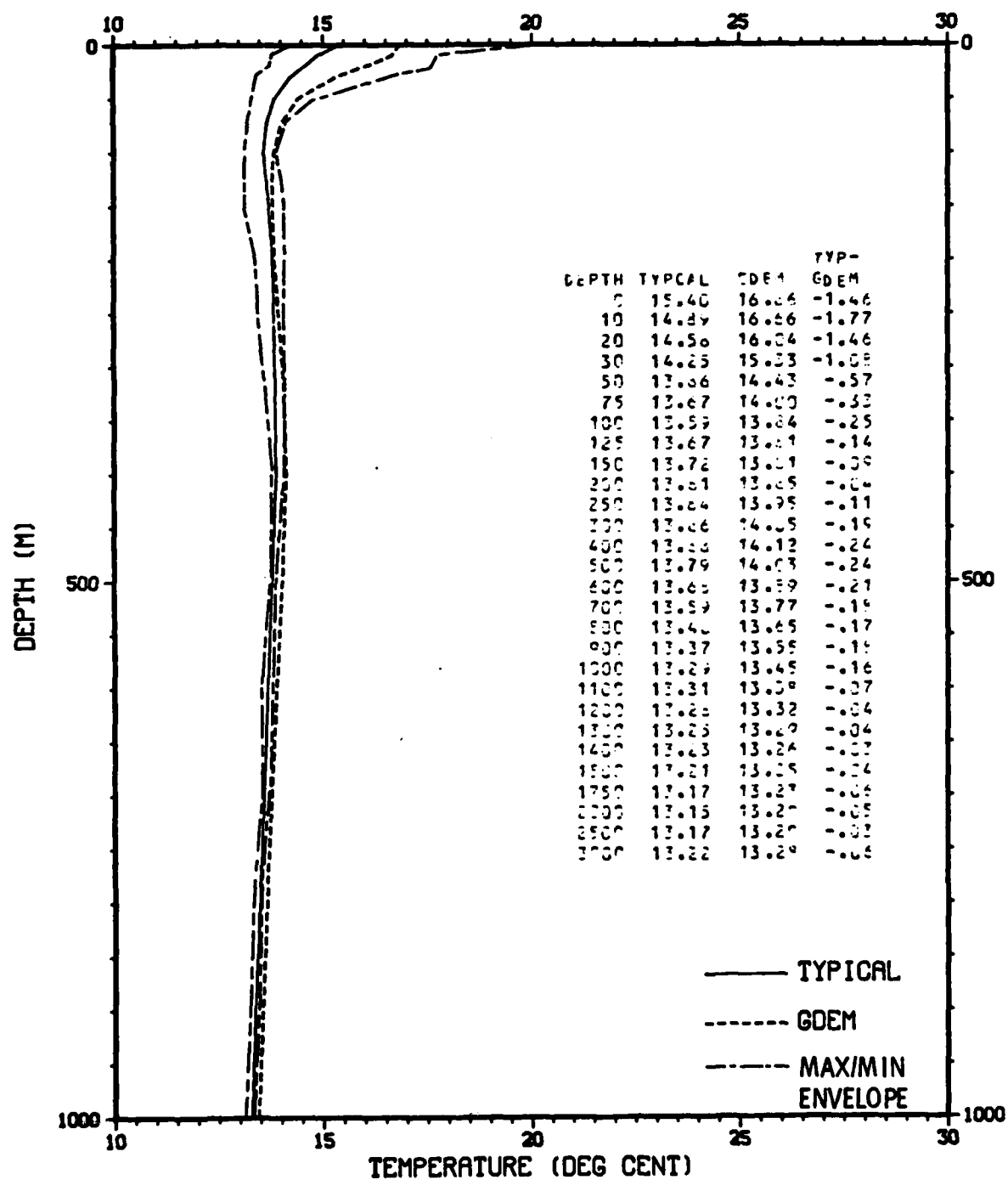


FIG. 4-2. VERTICAL TEMPERATURE PROFILE FOR TYRRHENIAN SEA (APR - JUN)

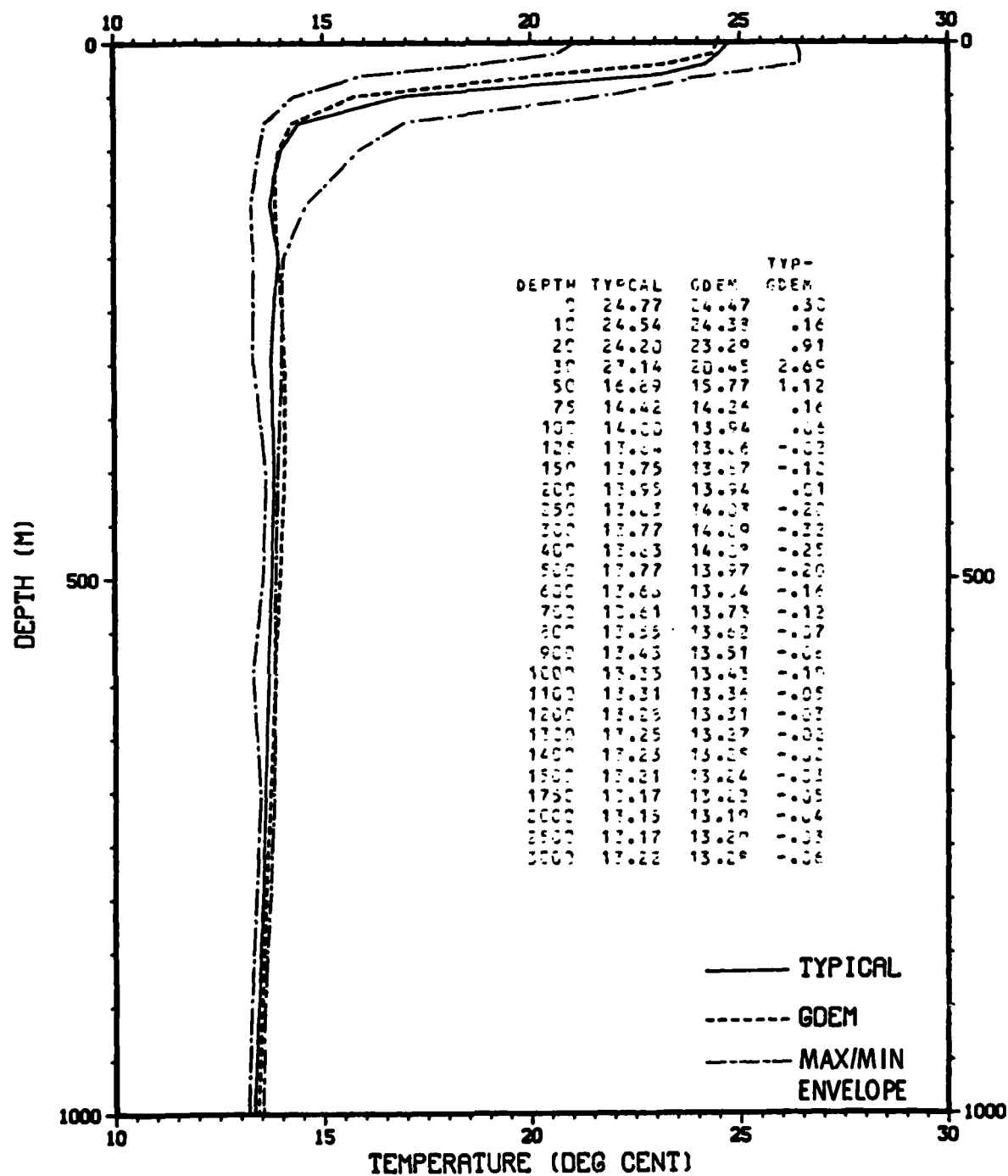


FIG. 4-3. VERTICAL TEMPERATURE PROFILE FOR TYRRHENIAN SEA (JUL - SEP)



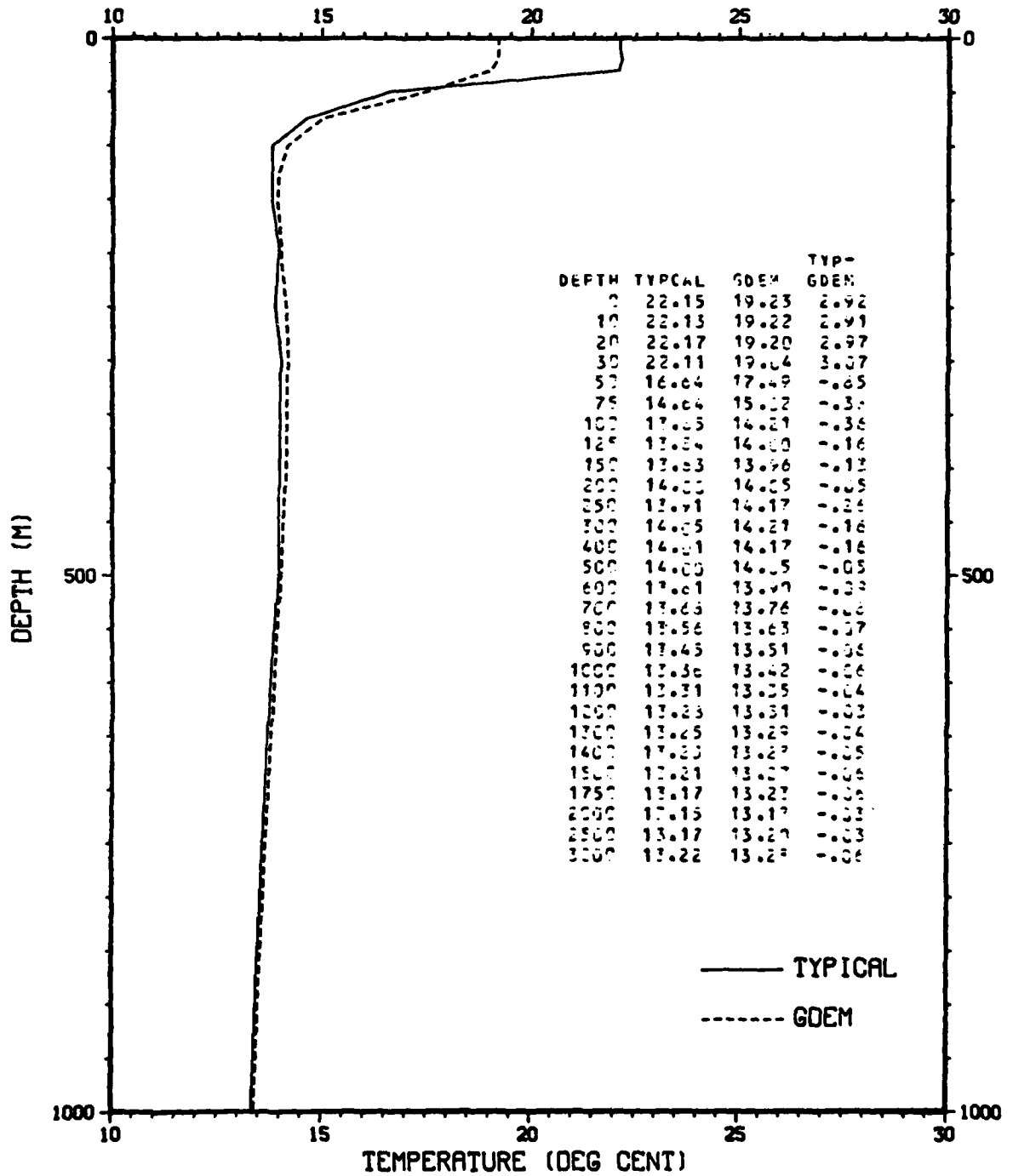


FIG. 4-4. VERTICAL TEMPERATURE PROFILE FOR TYRRHENIAN SEA (OCT - DEC)

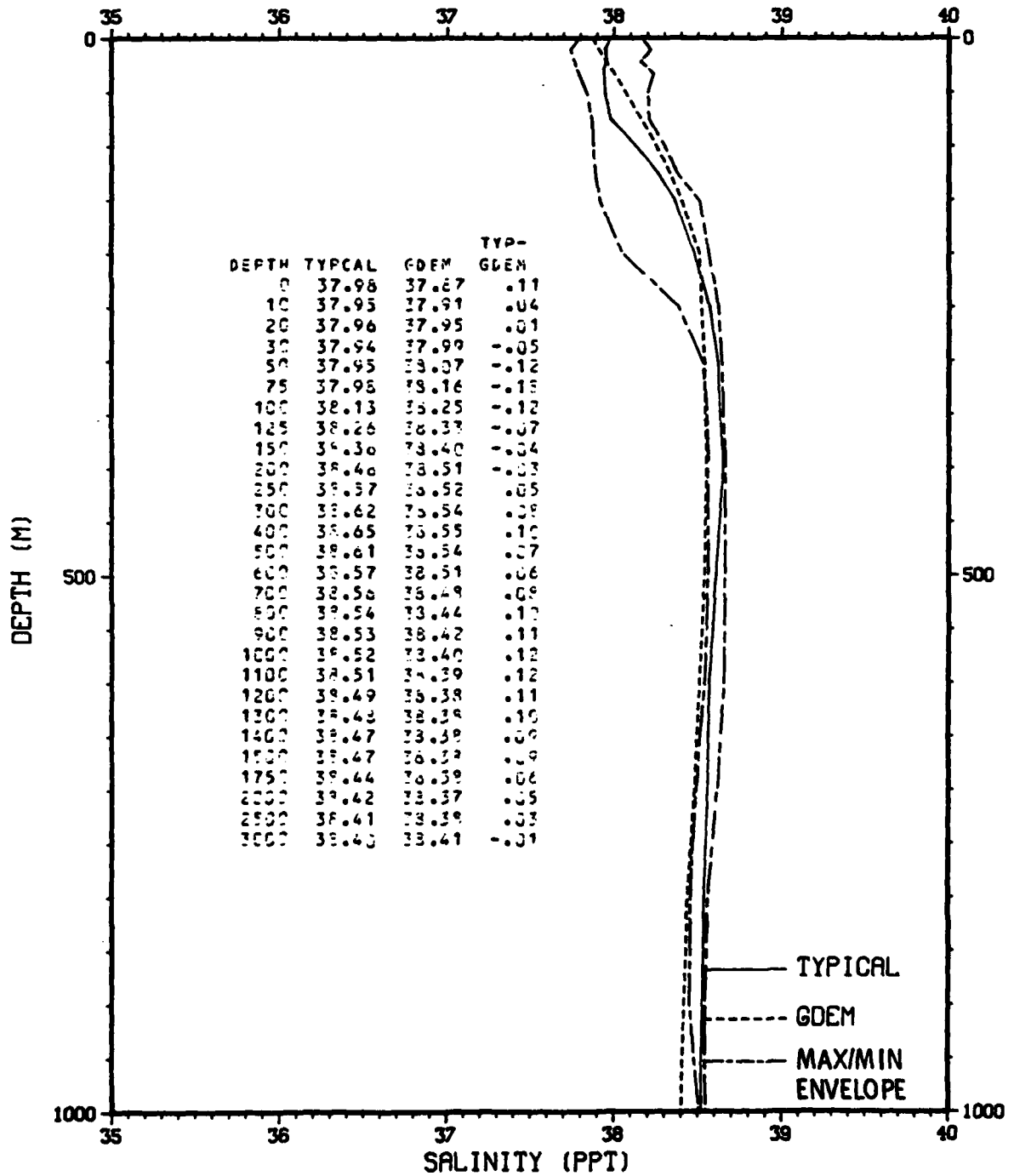


FIG. 4-5. VERTICAL SALINITY PROFILE FOR TYRRHENIAN SEA (JAN - MAR)

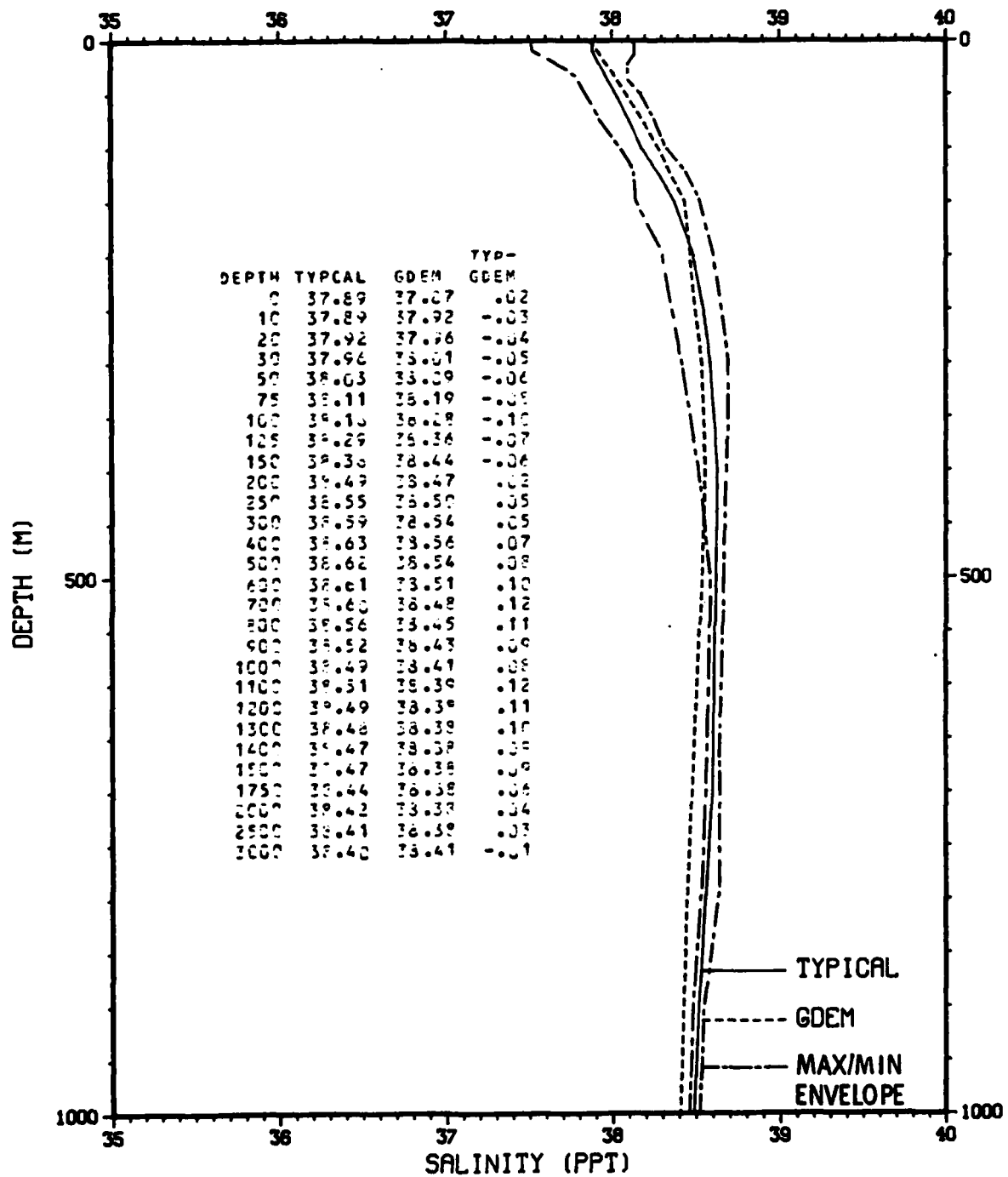


FIG. 4-6. VERTICAL SALINITY PROFILE FOR TYRRHENIAN SEA (APR - JUN)

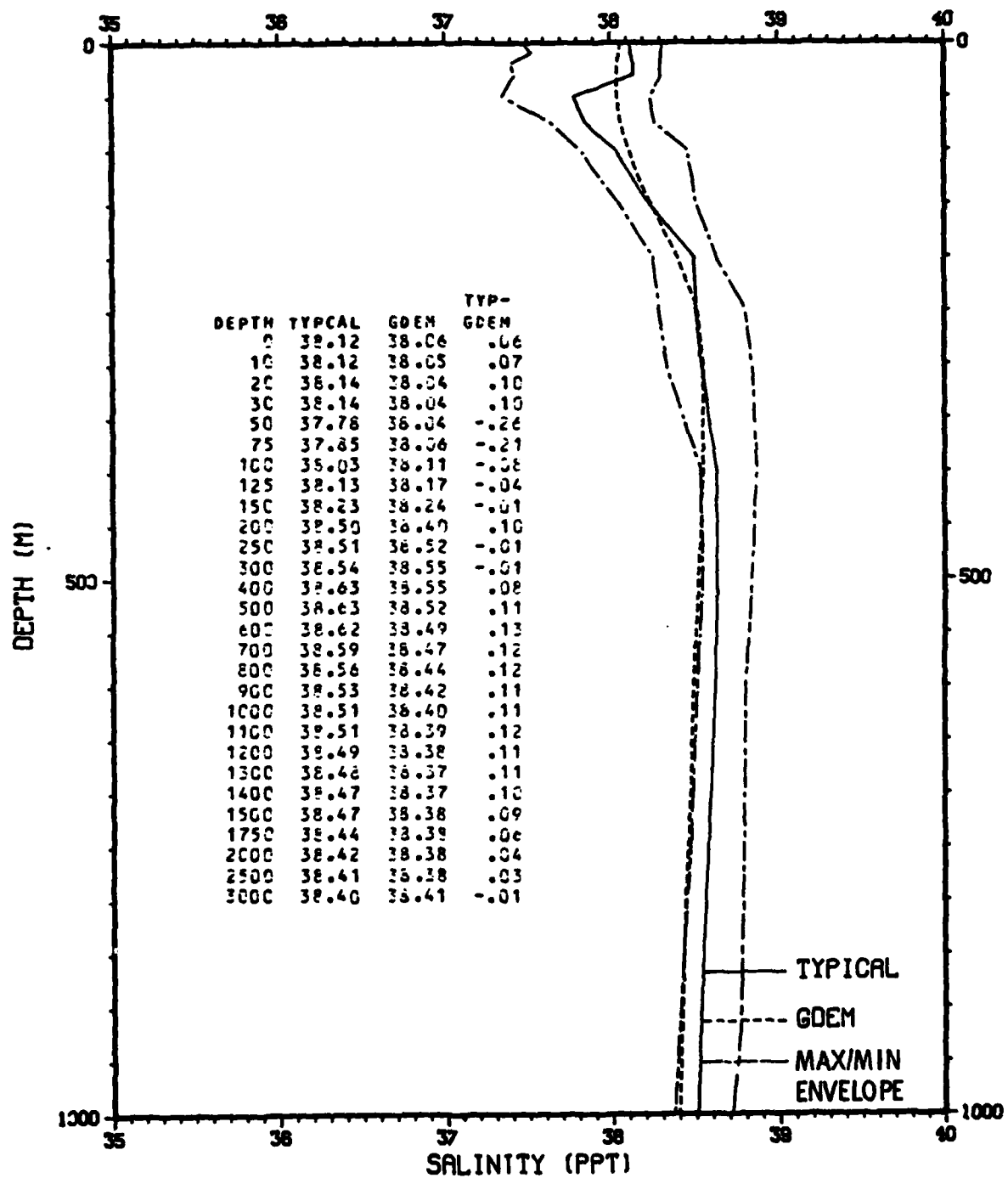


FIG. 4-7. VERTICAL SALINITY PROFILE FOR TYRRHENIAN SEA (JUL - SEP)

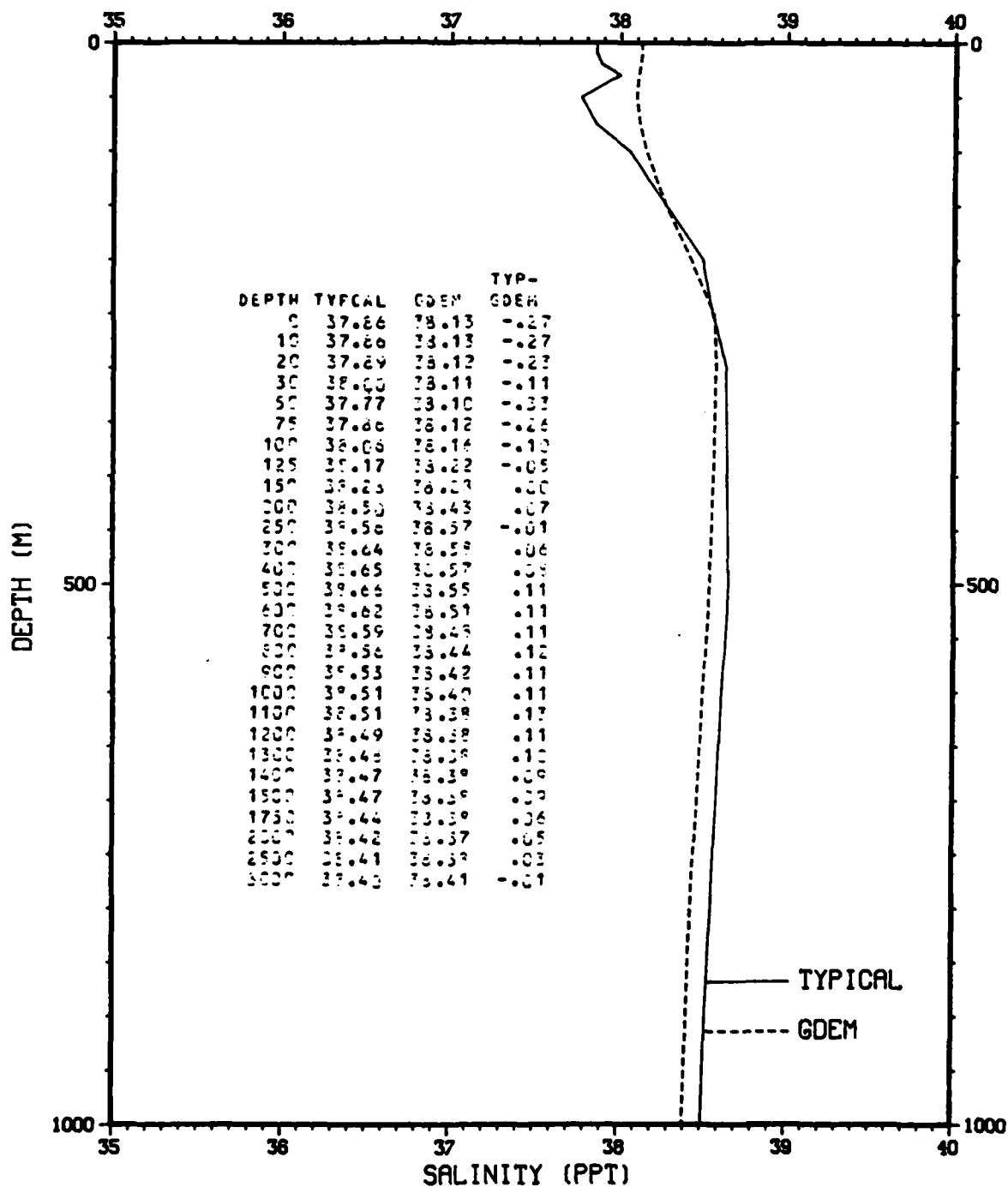


FIG. 4-8. VERTICAL SALINITY PROFILE FOR TYRRHENIAN SEA (OCT - DEC)

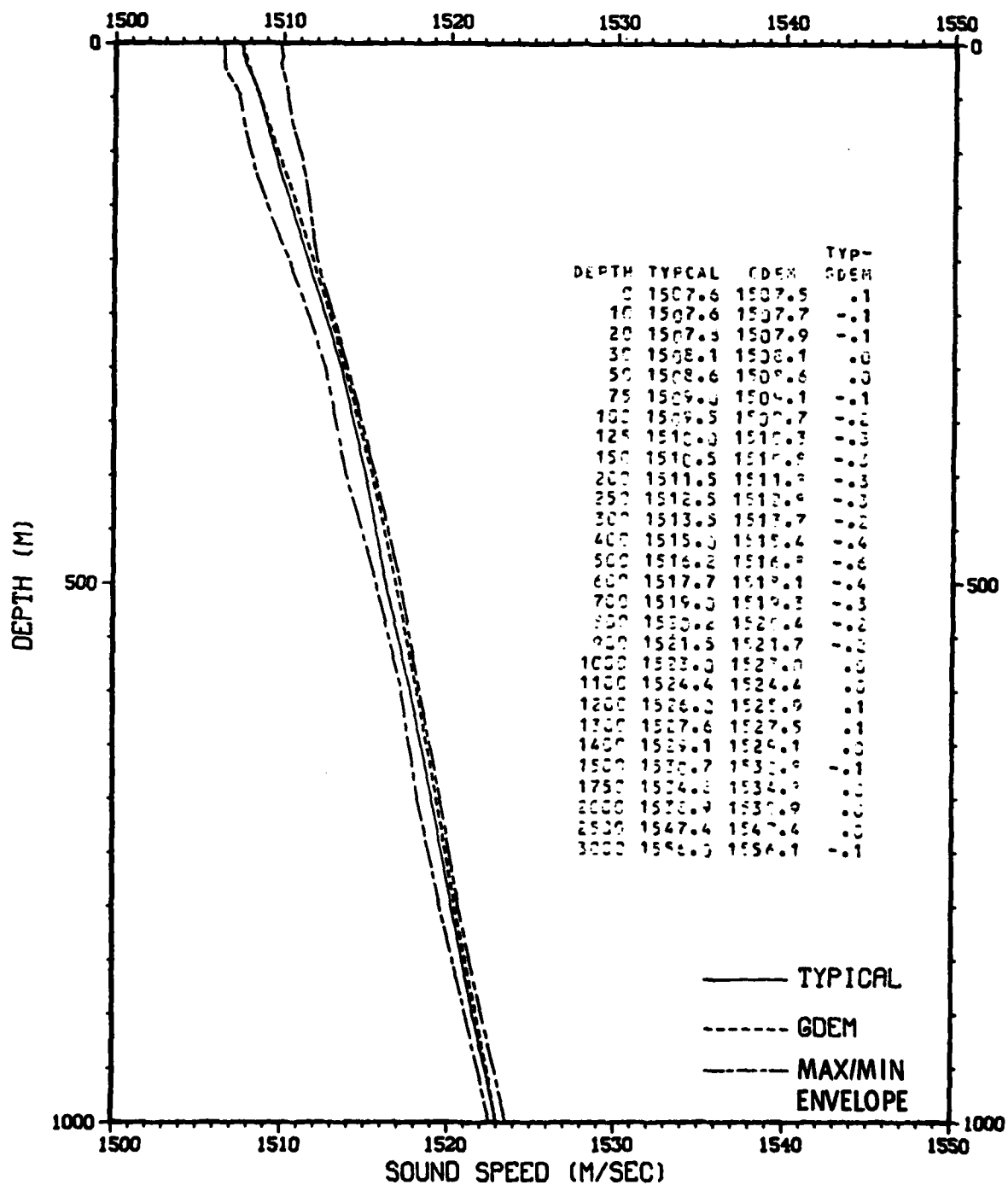


FIG. 4-9. VERTICAL SOUND-SPEED PROFILE FOR TYRRHENIAN SEA (JAN - MAR)

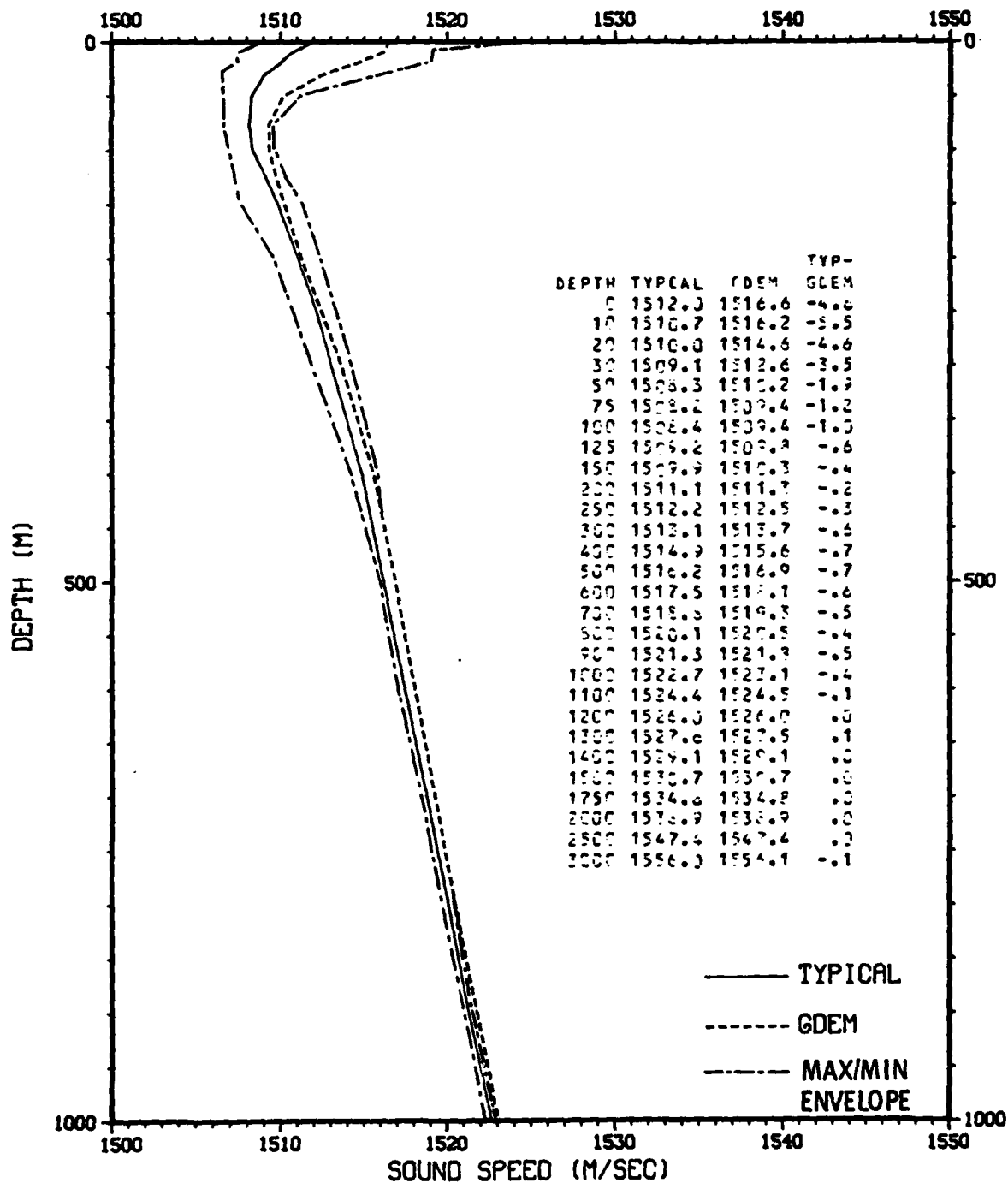


FIG. 4-10. VERTICAL SOUND-SPEED PROFILE FOR TYRRHENIAN SEA (APR - JUN)

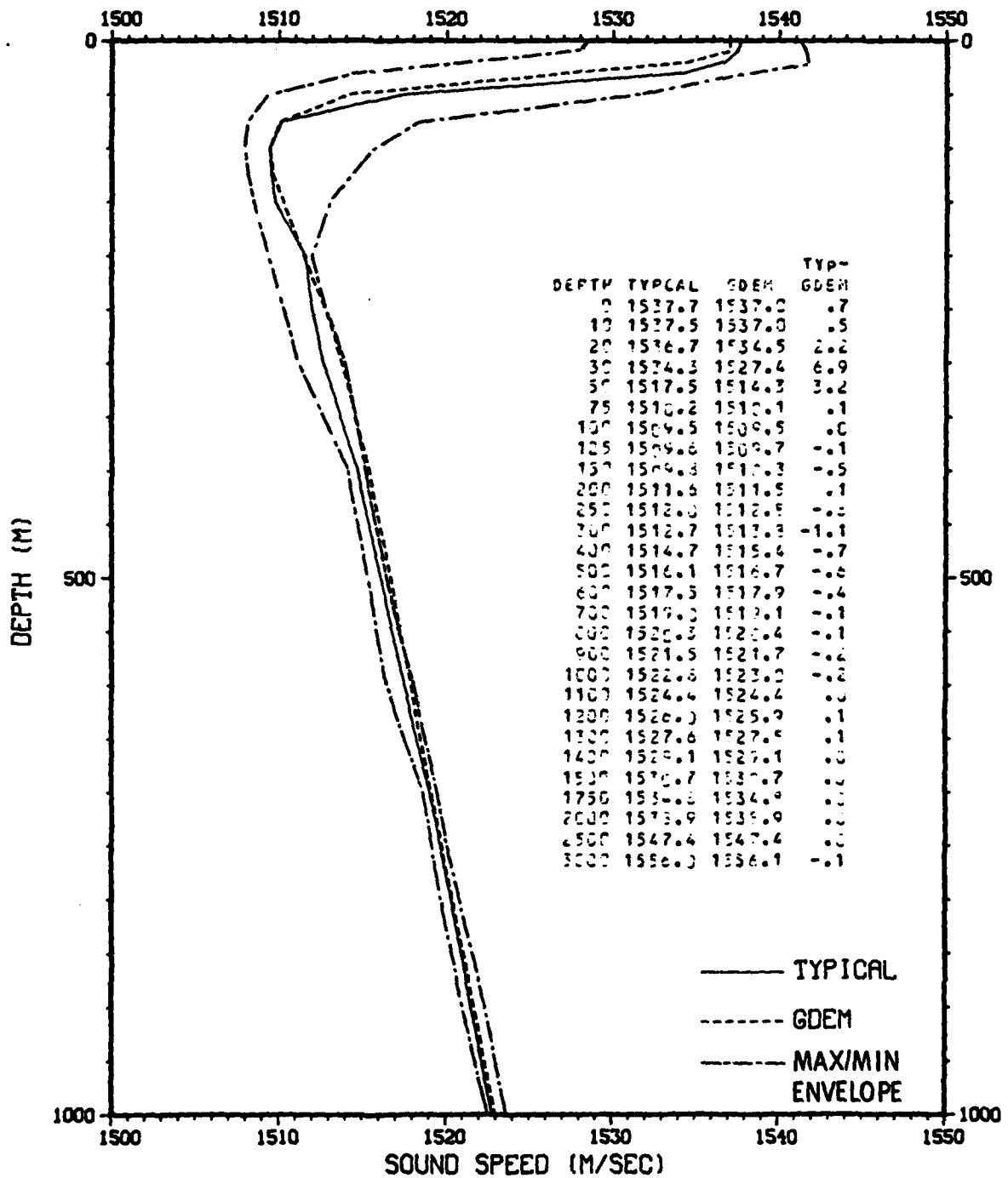


FIG. 4-11. VERTICAL SOUND-SPEED PROFILE FOR TYRRHENIAN SEA (JUL - SEP)



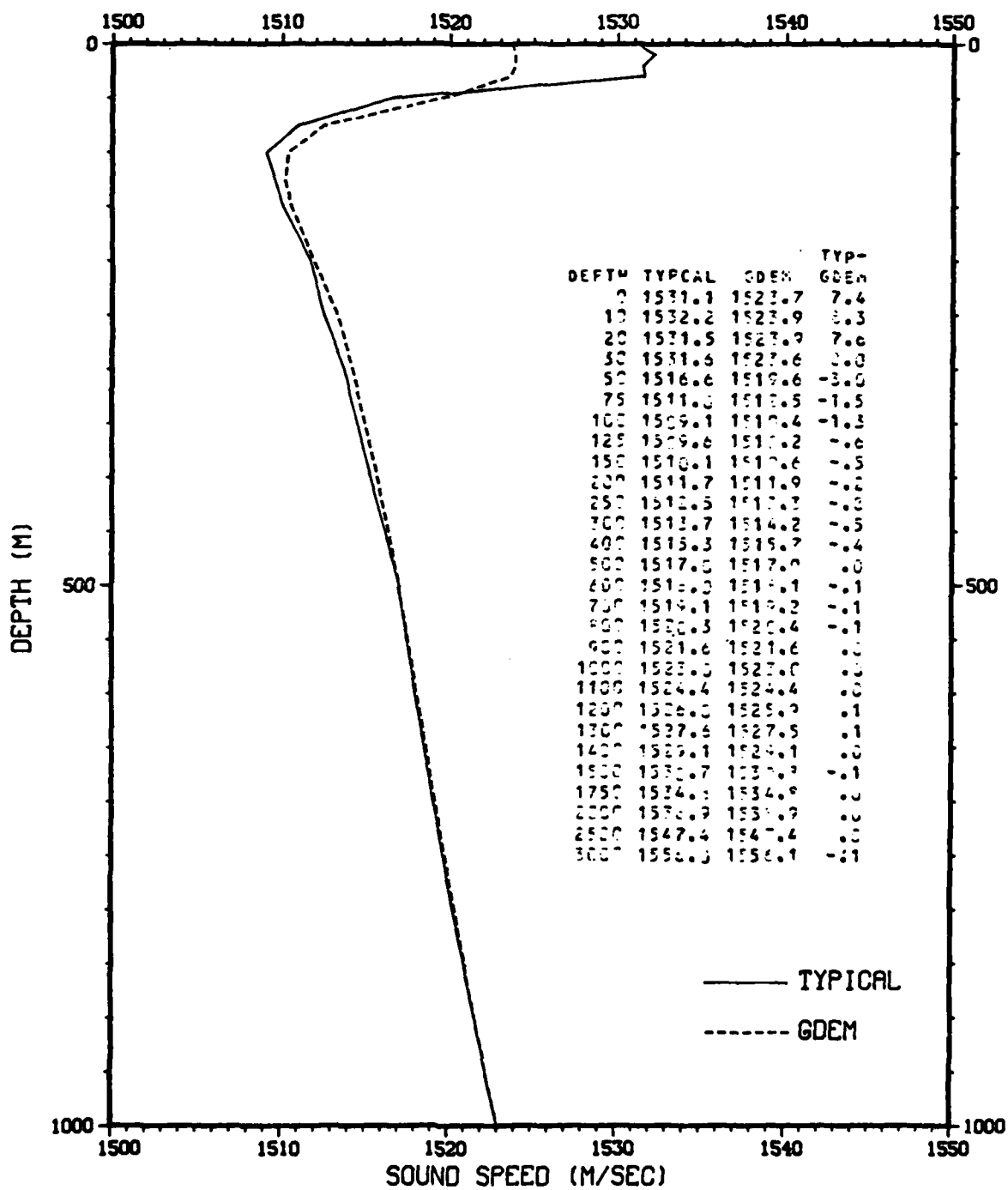


FIG. 4-12. VERTICAL SOUND-SPEED PROFILE FOR TYRRHENIAN SEA (OCT - DEC)

## 5.0 VERTICAL TEMPERATURE, SALINITY, AND SOUND-SPEED PROFILE COMPARISONS FOR MEDITERRANEAN (MED) LOCATION #4

Twelve vertical comparisons of temperature (T), salinity (S), and sound-speed (SS) for winter, spring, summer, and fall seasons are presented in this section.

### 5.1 Description

Med Location #4 is taken from the Strait of Sicily region of the Mediterranean Sea. The geographical location selected for this comparison is at 37°30' north latitude and 011°30' east longitude. Vertical temperature, salinity, and sound-speed profiles of seasonal comparisons are shown in Figures 5-1 through 5-12.

The Strait of Sicily region of the central Mediterranean Sea, depicted as Region D on Figure 1-1, is defined for this report as the body of water located at the passageway that separates the southern Tyrrhenian Sea from the extreme western portion of the eastern Mediterranean basin. The immediate and major land masses present in this region are the coastline of Tunisia and the island of Sicily.

Meteorologically, this region is considered somewhat variable to highly variable and influenced heavily by the Atlas Mountains. Although known as a zone for cyclogenesis, the Atlas Mountains appear to function as a barrier for the Strait of Sicily region. The net results of this barrier effect are delays in the rapid formation of North African cyclones and in the directing of North African cyclones away from the Strait of Sicily and toward the Gulf of Gabes.

Oceanographically, this region is considered highly variable and significant to the exchange of flow between the major eastern and western Mediterranean basins. Bathymetric features in this region play a dominant role in the oceanographic activity. A long channel-shaped basin, with a northwest-to-southeast orientation, cuts deep into the shelf that lies between Tunisia and Sicily. Also, what is often referred to as a "system of sills"

separates the major basins of the Mediterranean Sea. Unlike the exchange of North Atlantic water over the sill (not a system of sills) at the Strait of Gibraltar, the exchange of water and flow patterns that occur at the Strait of Sicily are between several secondary basins in this region. The main oceanographic process in this region occurs at subsurface levels. The well-known Levantine Water from the eastern Mediterranean flows westerly at varying depths, and fills the various secondary basins that precede the shallower shelf of the Strait of Sicily. The flow of the Levantine Water (characterized by a salinity maximum) is channeled through the Strait into the Tyrrhenian Basin, and assumes (based on the so-called "core method") a counterclockwise flow pattern. This channeling at the shelf is the primary factor that allows and provides for the exchange of subsurface flow between the two major basins. This flow of Levantine Water at the Strait of Sicily is often referred to as the Levantine Intermediate Current (reaching high velocities at approximately 250 m in depth of around 100 cm/sec or 2 kts). The strength of the Levantine Intermediate Current is perceptively stronger in the winter than in the summer.

## 5.2 Comparisons for Location #4

The vertical site comparisons of seasonal temperature, salinity, and sound-speed profiles, respectively, are presented for Med Location #4.

- **Temperature:**

The January-to-March temperature envelope taken from the statistical summaries was based on a data sample size of only five observations (Figure 5-1). The GDEM value at the surface falls within the established envelope of observed values. No numerical difference exists at the surface between the typical and GDEM. The GDEM vertical profile remains within the envelope down to approximately 300 m. The 300 to 400 m levels appear to reflect slightly higher (but do not exceed 0.3°C) values than the typical. The GDEM values below 400 m cannot be properly evaluated with the existing statistical summaries, because of the lack of sufficient observations.

The April-to-June temperature envelope taken from the statistical summaries was based on a data sample size of 28 observations

(Figure 5-2). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by  $1.82^{\circ}\text{C}$ . The GDEM profile remains within the envelope down to 100 m. Below 100 m, the GDEM profile (between 100 to 400 m) noticeably presents itself outside the envelope. This results in higher GDEM values of  $1.0^{\circ}\text{C}$  to  $1.3^{\circ}\text{C}$ . Below 500 m, the GDEM profile reverts back toward the typical.

The July-to-September temperature envelope taken from the statistical summaries was based on a data sample size of 14 observations (Figure 5-3). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by  $0.74^{\circ}\text{C}$ . Between the 20 and 30 m levels, there is a difference of  $1.3^{\circ}\text{C}$  to  $2.5^{\circ}\text{C}$ . Below 50 m down to 700 m, differences do not exceed  $0.8^{\circ}\text{C}$  (at 75 m) and are in near agreement ( $0.01^{\circ}\text{C}$  to  $0.07^{\circ}\text{C}$ ).

The October-to-December temperature envelope taken from the statistical summaries was based on a data sample size of only six observations (Figure 5-4). The GDEM value at the surface does not fall within the envelope of observed values and differs from the typical by  $1.84^{\circ}\text{C}$ . This difference (approximately  $1.8^{\circ}\text{C}$  to  $1.9^{\circ}\text{C}$ ) continues to occur from the surface down to 50 m. Below 50 m, the GDEM values fall within the envelope. Differences that occur within the envelope between the GDEM and typical below 100 m are less than  $0.3^{\circ}\text{C}$ .

- Salinity:

The January-to-March salinity envelope taken from the statistical summaries was based on a data sample size of only five observations (Figure 5-5). The GDEM value at the surface does not fall within the envelope of observed values. A numerical difference of 0.50 ppt exists at the surface between the typical and GDEM. Differences on the order of 0.50 ppt remain down to 30 m. Between the 50 to 150 m levels, the differences are less than 0.43 ppt. Below 200 m, the differences do not exceed 0.15 ppt and appear to reflect GDEM as slightly lower in value.

The April-to-June salinity envelope taken from the statistical summaries was based on a data sample size of 28 observations (Figure 5-6). The GDEM value at the surface does fall within the envelope of observed values and differs from the typical by only 0.26 ppt. Differences on the order of 0.33 ppt remains down to 100 m. Below 150 m, the differences are slight (less than 0.16 ppt) and reflect closer agreement.

The July-to-September salinity envelope taken from the statistical summaries was based on a data sample size of 14 observations

(Figure 5-7). The GDEM value at the surface falls within the envelope of observed values and differs from the typical by only 0.09 ppt. Between 50 to 150 m levels, the differences are on the order of approximately 0.27 ppt. Below 200 m, the differences are slight (less than 0.17 ppt), and appear to reflect GDEM as slightly lower in value.

The October-to-December salinity envelope taken from the statistical summaries was based on a data sample size of only six observations (Figure 5-8). The GDEM value at the surface falls outside the envelope of observed values and differs from the typical by 0.32 ppt. A consistent difference of approximately 0.30 ppt to 0.40 ppt exists between 20 and 100 m. Below 150 m, the differences are slight (less than 0.17 ppt) and appear to reflect GDEM as slightly lower in value.

- Sound Speed:

The January-to-March sound-speed envelope taken from the statistical summaries was based on a data sample size of five observations (Figure 5-9). The GDEM value at the surface does not fall within the envelope of observed values but differs from the typical by only 0.7 m/s. Differences in value below the surface and down to 75 m do not exceed 0.9 m/s. Differences of 1.3 m/s, 1.1 m/s, and 1.0 m/s exist at the 100 m, 125 m, and 150 m levels, respectively. Below 150 m down to 700 m, all differences do not exceed 0.9 m/s.

The April-to-June sound-speed envelope taken from the statistical summaries was based on a data sample size of 28 observations (Figure 5-10). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by 5.6 m/s. Below the surface, the differences are noticeable. These differences range between 2.0 m/s and 5.3 m/s.

The July-to-September sound-speed envelope taken from the statistical summaries was based on a data sample size of 14 observations (Figure 5-11). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by 1.7 m/s. Differences in value below the surface and down to 150 m range between 0.7 and 6.7 m/s. Below 150 m, the maximum difference does not exceed 0.5 m/s.

The October-to-December sound-speed envelope taken from the statistical summaries was based on a data sample size of six observations (Figure 5-12). The GDEM value at the surface does not fall within the envelope of observed values and differs from the typical by 5.8 m/s. Differences in value below the surface and down to 75 m range between 4.6 m/s and 6.2 m/s. Below 125 m, the maximum difference does not exceed 0.9 m/s.

### 5.3 Evaluation - Strait of Sicily (Location #4)

- January to March:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in the thermal structures. The differences in the absolute values are quite small from the surface down to 700 m. The GDEM profile is nearly identical to the typical. The envelope is quite narrow and may not be a proper representation of the expected range of values. This region is shallow and known for a wide range of variabilities in the temporal and spatial domains. The GDEM appears to reflect a reasonable seasonally averaged winter thermal structure for this highly variable ocean region when compared with the five usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals little similarity in the haline structures. In addition to the differences in the surface values (0.50 ppt), the near-surface halocline and below-halocline gradients are different. The envelope is viewed too narrow near the surface layers and considered as being biased toward the minimum range of values. The surface salinities for this location and time period can range up to values of 37.55 ppt. The envelope does not reflect a proper range of variability. The GDEM surface value appears reasonable and representative. The GDEM salinity profile below 300 m appears too low by perhaps 0.08 ppt to 0.15 ppt.

An evaluation of the GDEM and typical sound-speed profile comparison reveals similarities in the sound-speed structures. The differences in the numerical values are small. The envelope below the surface and down to 100 m is too narrow for this highly variable ocean region. The seasonally averaged half-channel mode sound-speed profile is appropriate. The GDEM appears to reflect a reasonable seasonally averaged winter sound-speed structure for this highly variable region when compared with the five usable observations.

- April to June:

An evaluation of the GDEM and typical temperature profile comparison reveals a lack of adequate agreement for the numerical values in the thermal structures. The differences from the surfaces and down to 300 m reveals GDEM as consistently having values greater than  $1.0^{\circ}\text{C}$ ; however, the thermal gradients between 75 m down to 250 m are similar. The envelope indicates a predominant surface variability and a wide variability down to 300 m. Although the region is highly variable and relatively

shallow (approximately 700 m) for this location, the GDEM numerical values for temperature between 75 down to 700 m appear too high. The typical values appear reasonable and representative for spring thermal structure for this highly variable ocean region when compared with the 28 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals little similarity in the haline structure. The GDEM halocline is steeper (greater in gradient), reveals a well-defined subsurface salinity axis maxima at 300 m, and differs in value below 500 m in the isohaline zone by being approximately 0.14 ppt too low. The GDEM surface value is reasonable for this location. The surface envelope is considered too narrow for this location.

An evaluation of the GDEM and typical sound-speed profile comparison reveals a lack of adequate agreement in the numerical values of the sound-speed structures. The differences from the surface down to 300 m reveals GDEM as having values consistently greater than 3.0 m/s; however, the gradients below the sound channel axis (approximately 75 m) down to 200 m are similar. The GDEM reveals a secondary subsurface minimum (a secondary sound-channel axis) between 300 to 400 m. The differences in the values of sound speed above 300 m appear to be directly related to the over estimated temperature profile. The GDEM secondary subsurface minima appears to be influenced by the GDEM salinity profile. The typical sound-speed profile appears to be reasonable and representative for this highly variable ocean region when compared with the 28 usable observations.

- July to September:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in the thermal structures. The near-surface thermal gradients above 50 m are quite similar. The thermal gradients below 150 m and down to 700 m are also quite similar. There is a slight difference in the depth of the bottom of the thermoclines by approximately 25 m. The bottom of the GDEM thermocline is shallower in depth. Both GDEM and the typical reflect the general trends of the envelope. The GDEM appears to reflect a reasonable seasonally averaged summer thermal structure for this highly variable ocean region when compared with the 14 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals little similarity in haline structure. The near-surface GDEM halocline gradient is noticeably steeper (greater in gradient) and consistently lower in value below 100 m. The GDEM near-surface gradient appears too linear for a representation of a seasonal salinity profile for this location. The numerical values

below 150 m are perhaps too low and can be increased by approximately 0.06 ppt from 150 m down to 700 m. The GDEM surface value appears a little low. A thicker salinity minimum layer would be reasonable. The GDEM surface value is reasonable for this highly variable ocean region when compared with the 14 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals similarities in the sound-speed structures. The near-surface sonocline gradients above 50 m are quite similar. The sonocline gradients below 150 m down to 700 m are also quite similar. There is a slight difference in the depth of the sound-channel axis by approximately 25 m. GDEM is shallower. Because of the shallower depth of the sound-channel axis, the GDEM gradient immediately above the apex of the axis is greater. The GDEM appears to reflect a reasonable seasonally averaged summer sound-speed structure for this highly variable ocean region when compared with the 14 usable observations.

- October to December:

An evaluation of the GDEM and typical temperature profile comparison reveals some similarity. The GDEM surface value is higher than the typical and is outside the envelope. Below the near-surface layers (above 100 m), the thermal structures are similar. The width of the surface envelope is considered too narrow for this ocean region for this season. The area is known for a noticeable seasonally averaged fall variability. The GDEM surface value, thickness of the layer, and thermocline gradient are considered realistic, representative, and reasonable for a seasonally averaged fall thermal structure for this highly variable ocean region when compared with the four usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals little similarity in haline structure. GDEM lacks a surface-salinity minimum layer. The GDEM values from approximately 350 m down to 700 m are consistently lower but acceptable. The surface envelope is considered too narrow for this location. The GDEM surface value appears reasonable. A surface salinity minimum layer would represent a more realistic seasonal salinity profile for this highly variable ocean region.

An evaluation of the GDEM and typical sound-speed profile comparison reveals some similarities in sound-speed structure. The GDEM surface value is noticeably higher but realistic for this location. A well-defined shallow surface duct is reasonable for this period of time. The depth of the sound-channel axis of GDEM and the typical are the same. The GDEM appears to represent an acceptable seasonally averaged winter sound-speed structure for this highly variable ocean region when compared with the four usable observations.



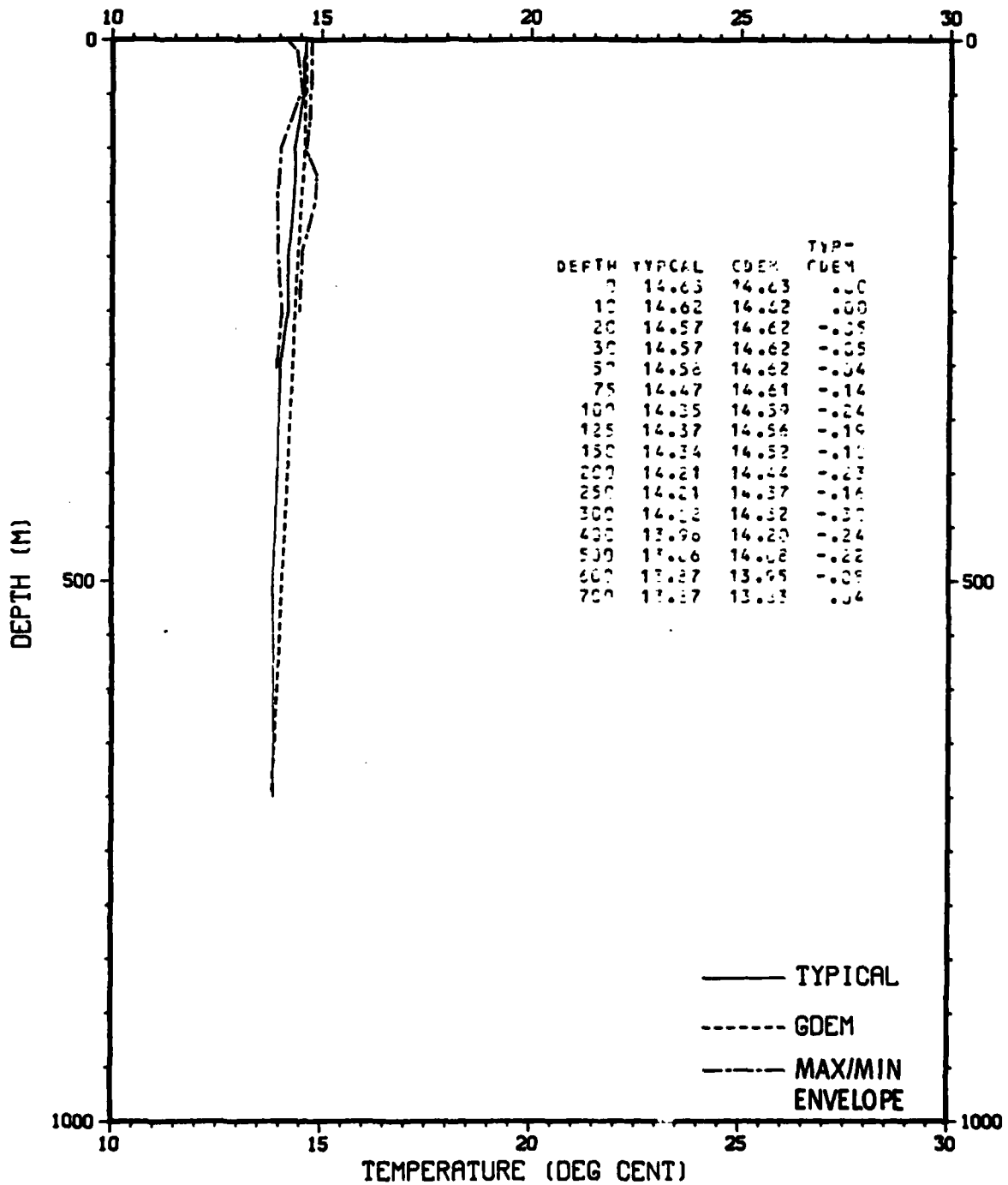


FIG. 5-1. VERTICAL TEMPERATURE PROFILE FOR STRAIT OF SICILY (JAN - MAR)

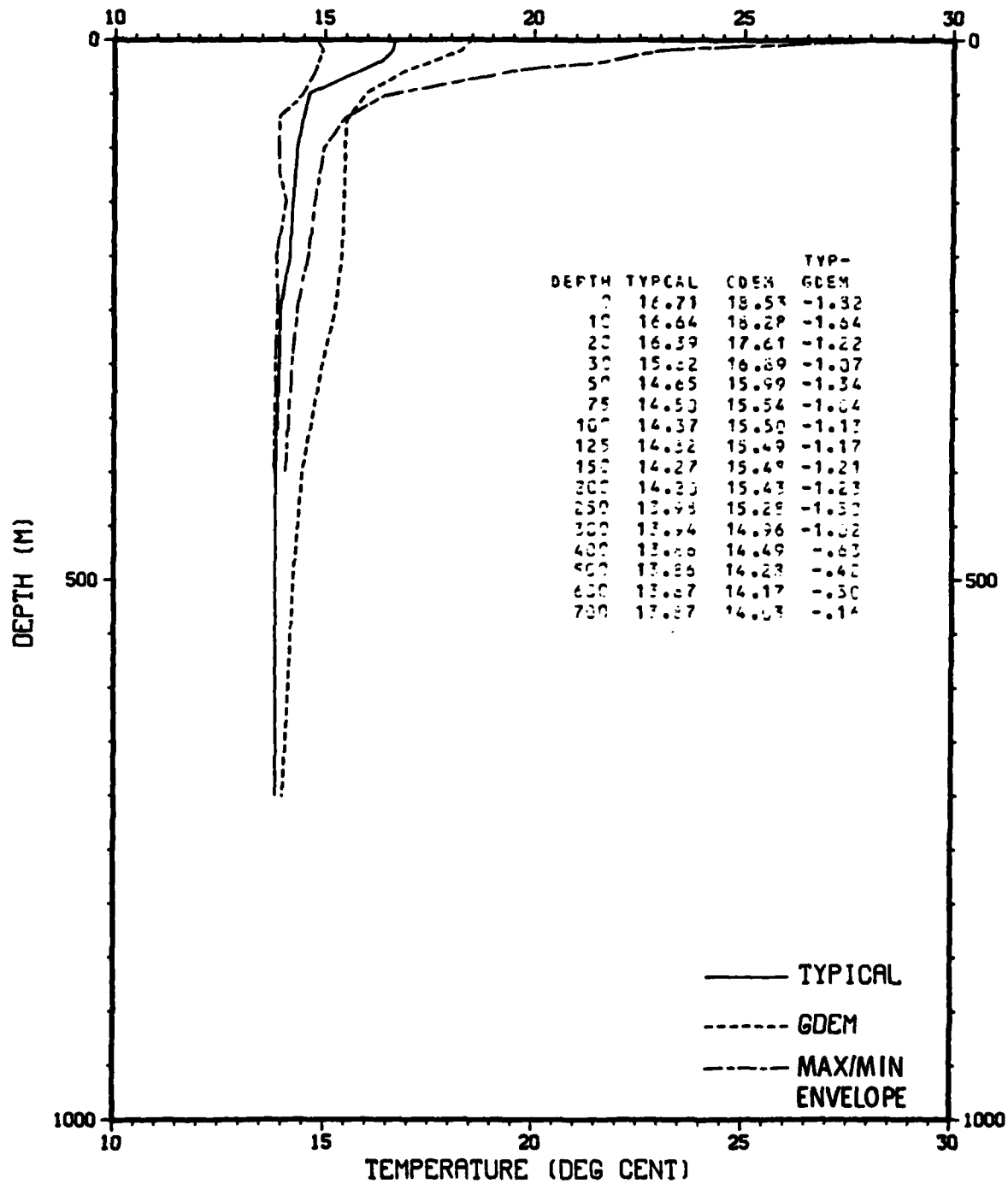


FIG. 5-2. VERTICAL TEMPERATURE PROFILE FOR STRAIT OF SICILY (APR - JUN)

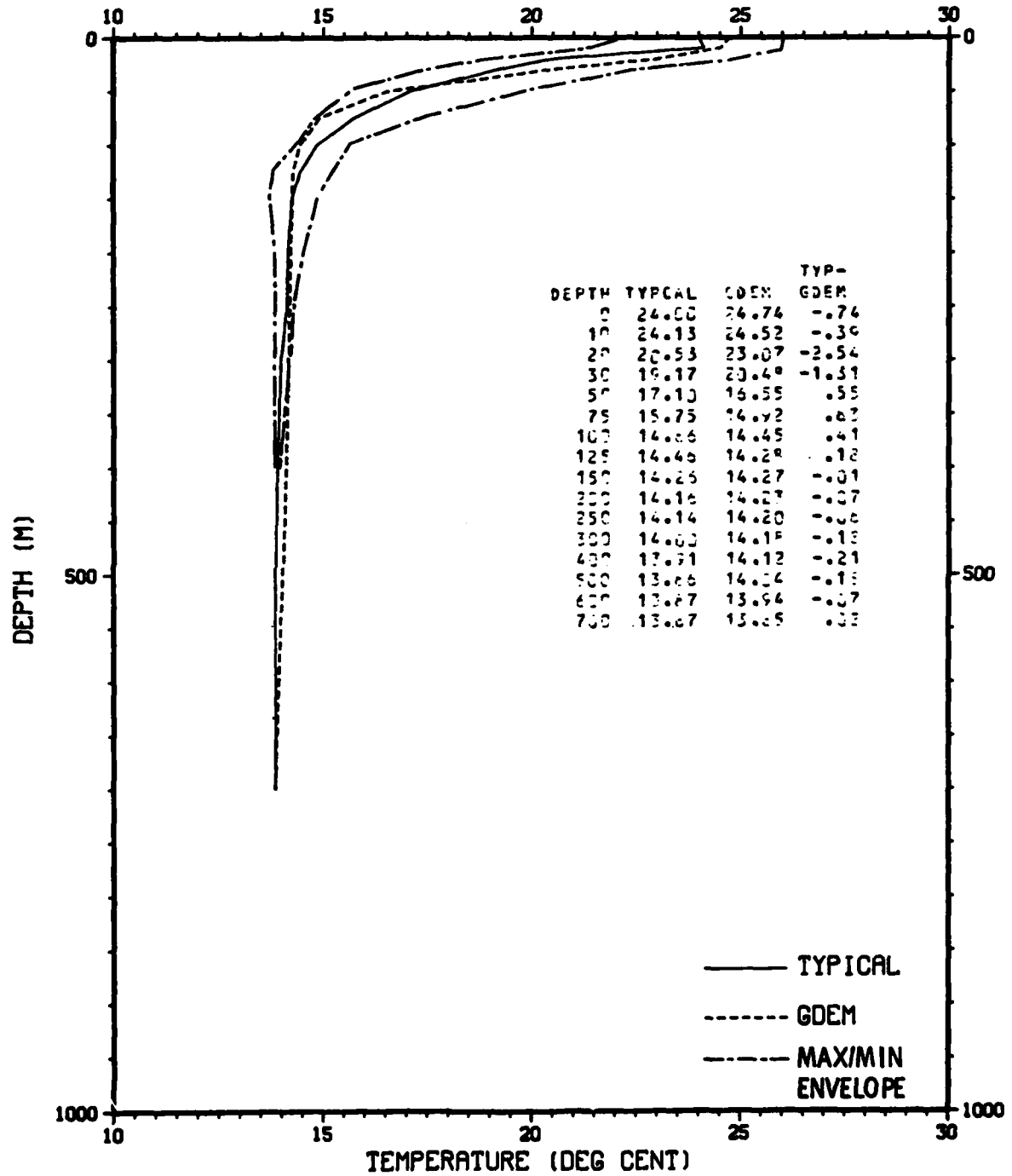


FIG. 5-3. VERTICAL TEMPERATURE PROFILE FOR STRAIT OF SICILY (JUL - SEP)

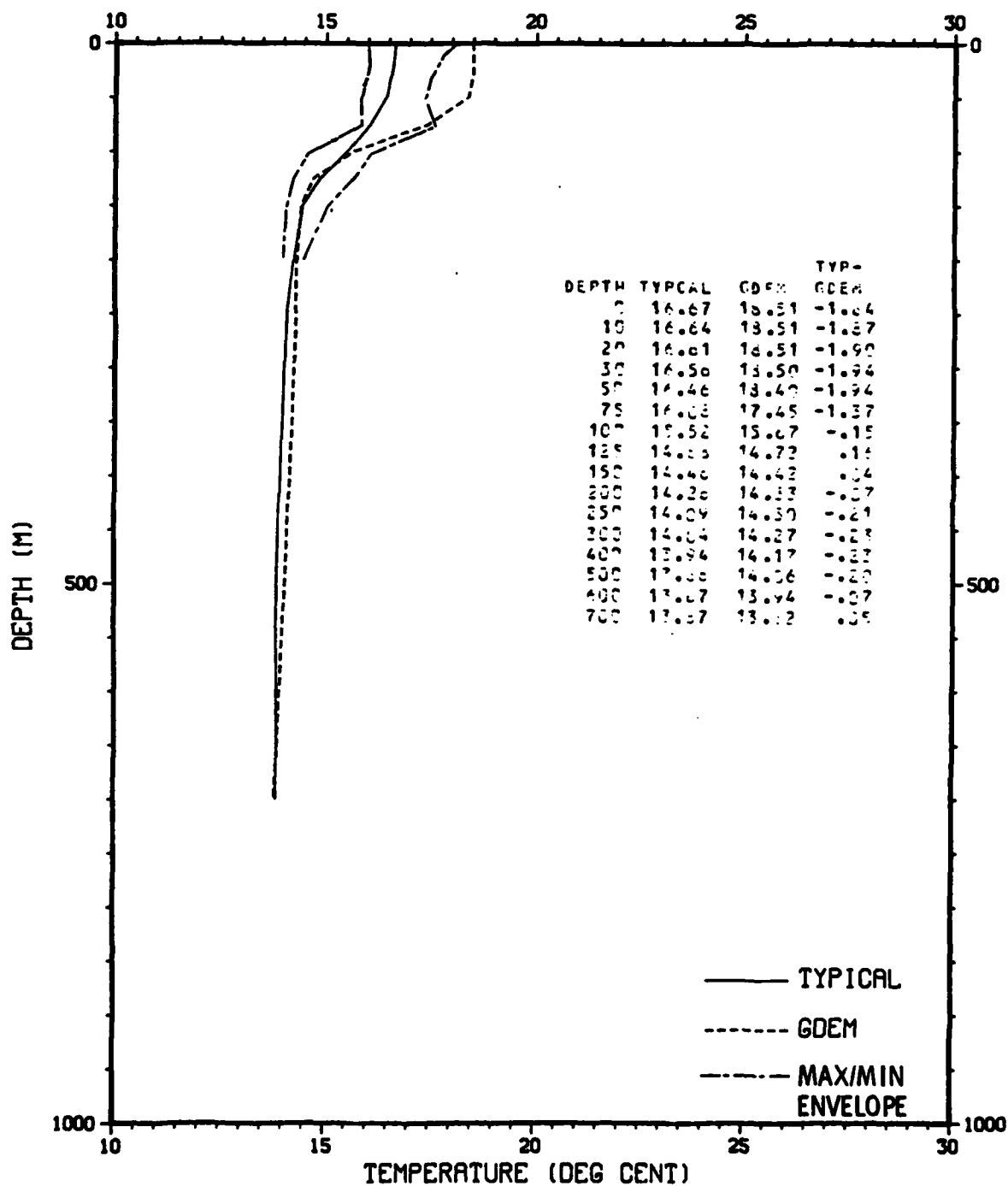


FIG. 5-4. VERTICAL TEMPERATURE PROFILE FOR STRAIT OF SICILY (OCT - DEC)

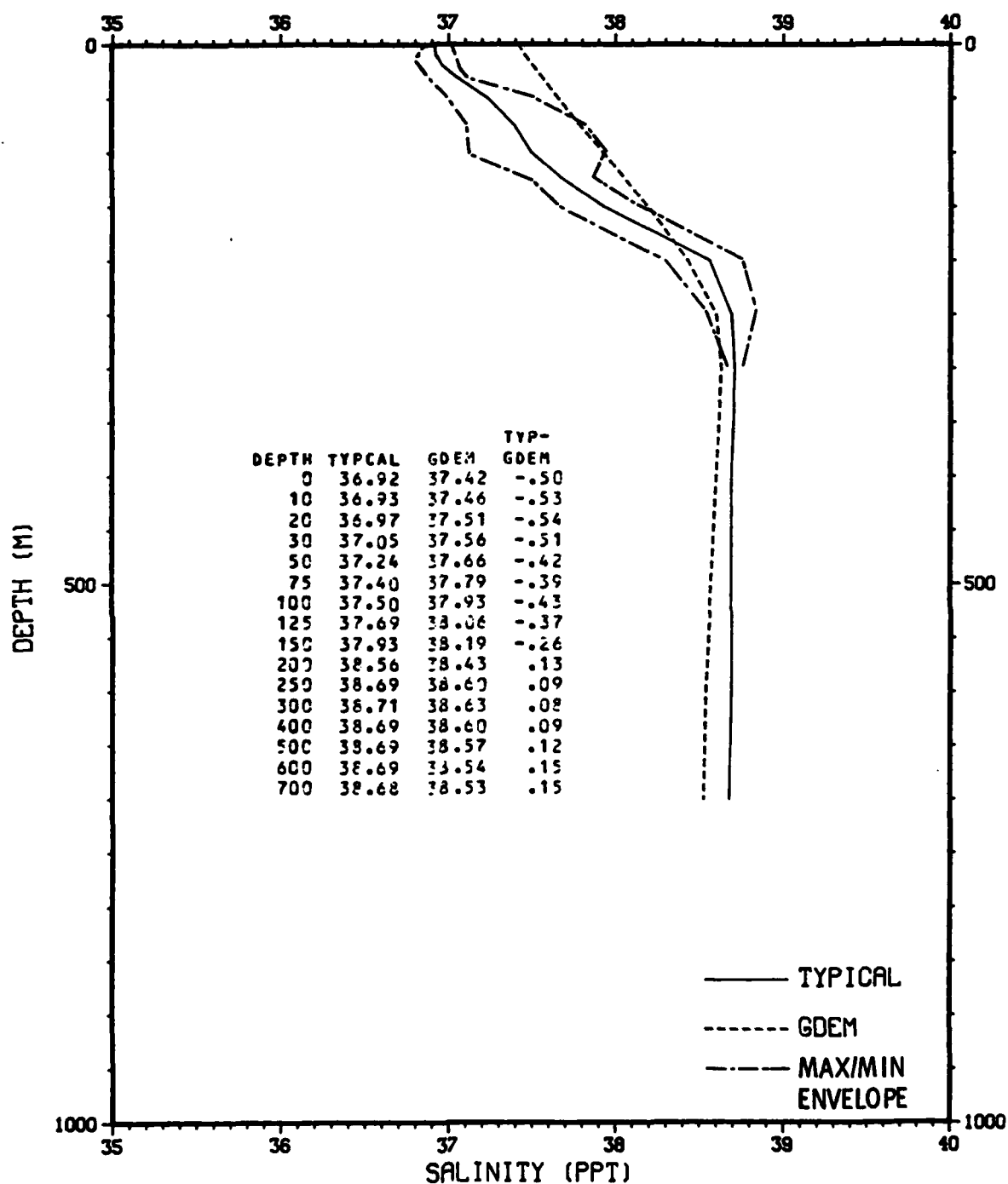


FIG. 5-5. VERTICAL SALINITY PROFILE FOR STRAIT OF SICILY (JAN - MAR)

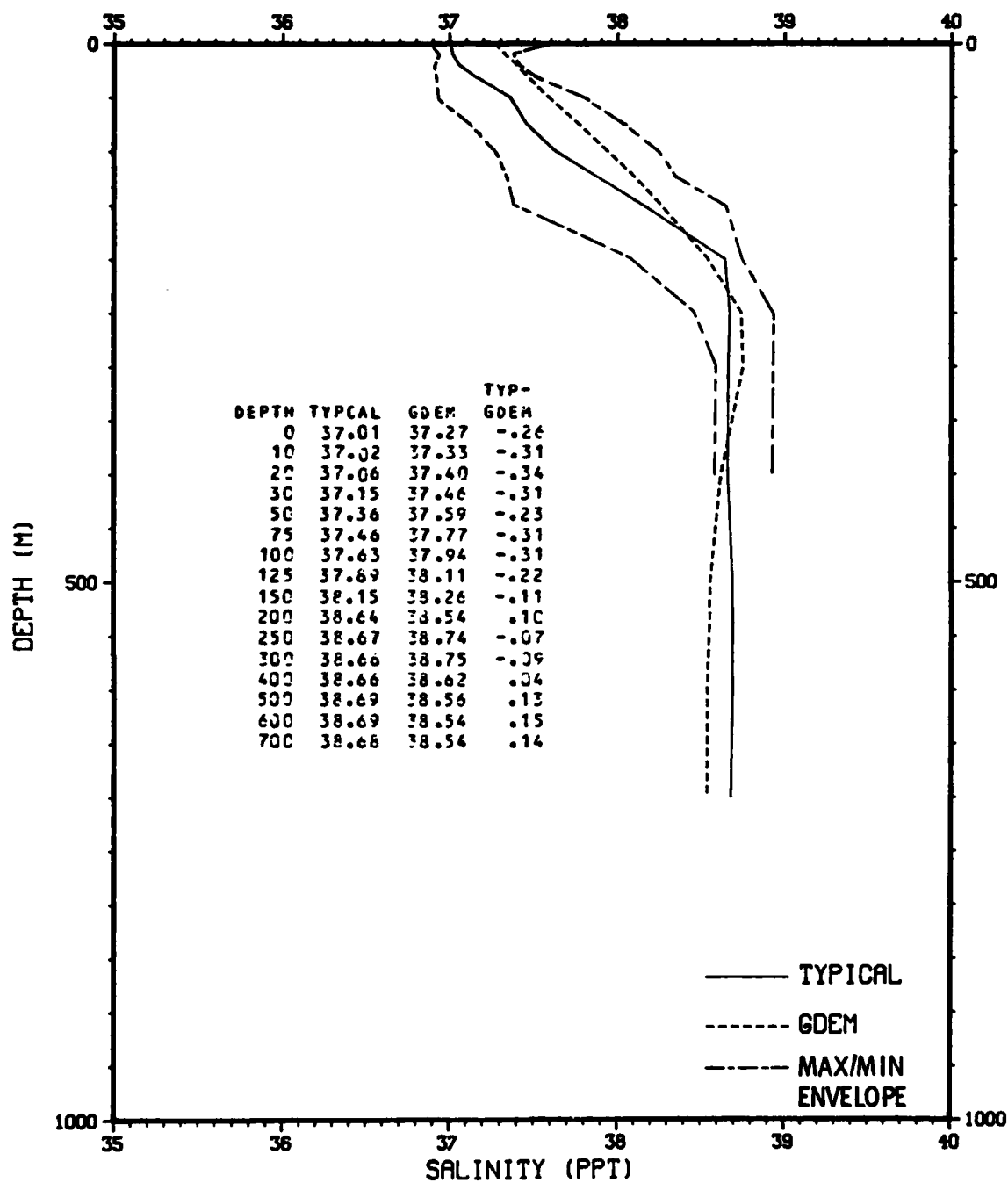


FIG. 5-6. VERTICAL SALINITY PROFILE FOR STRAIT OF SICILY (APR - JUN)

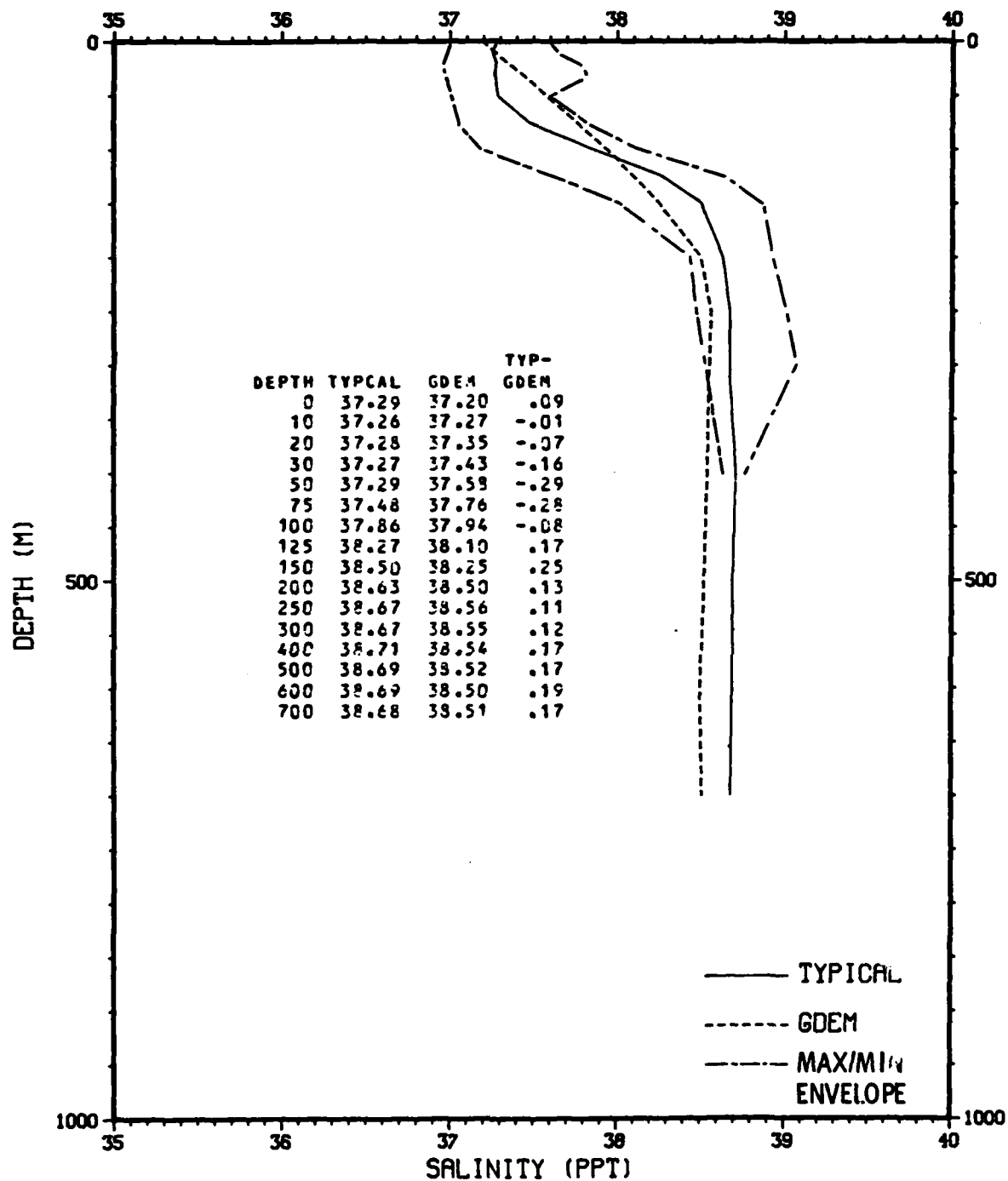


FIG. 5-7. VERTICAL SALINITY PROFILE FOR STRAIT OF SICILY (JUL - SEP)

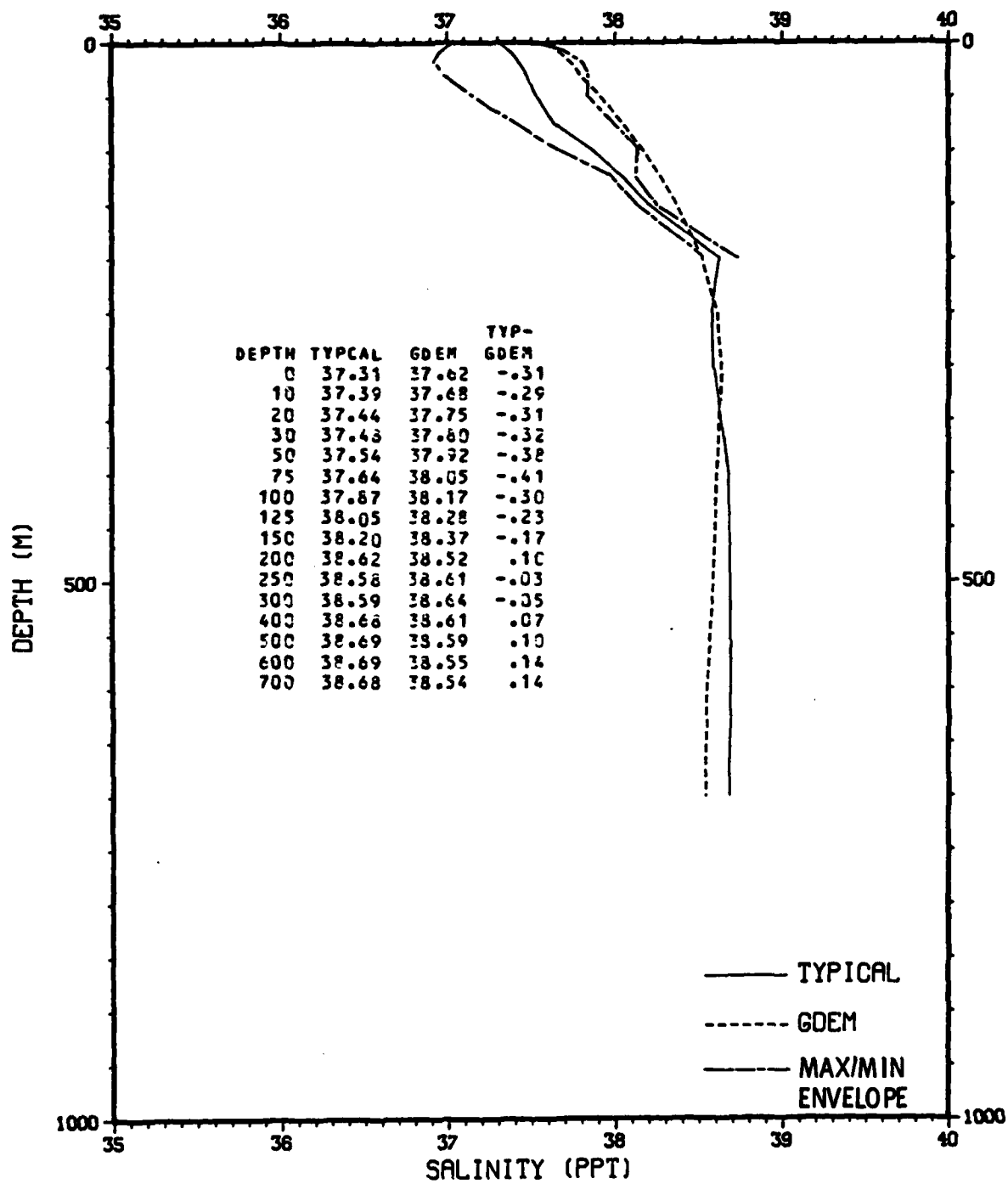


FIG. 5-8. VERTICAL SALINITY PROFILE FOR STRAIT OF SICILY (OCT - DEC)



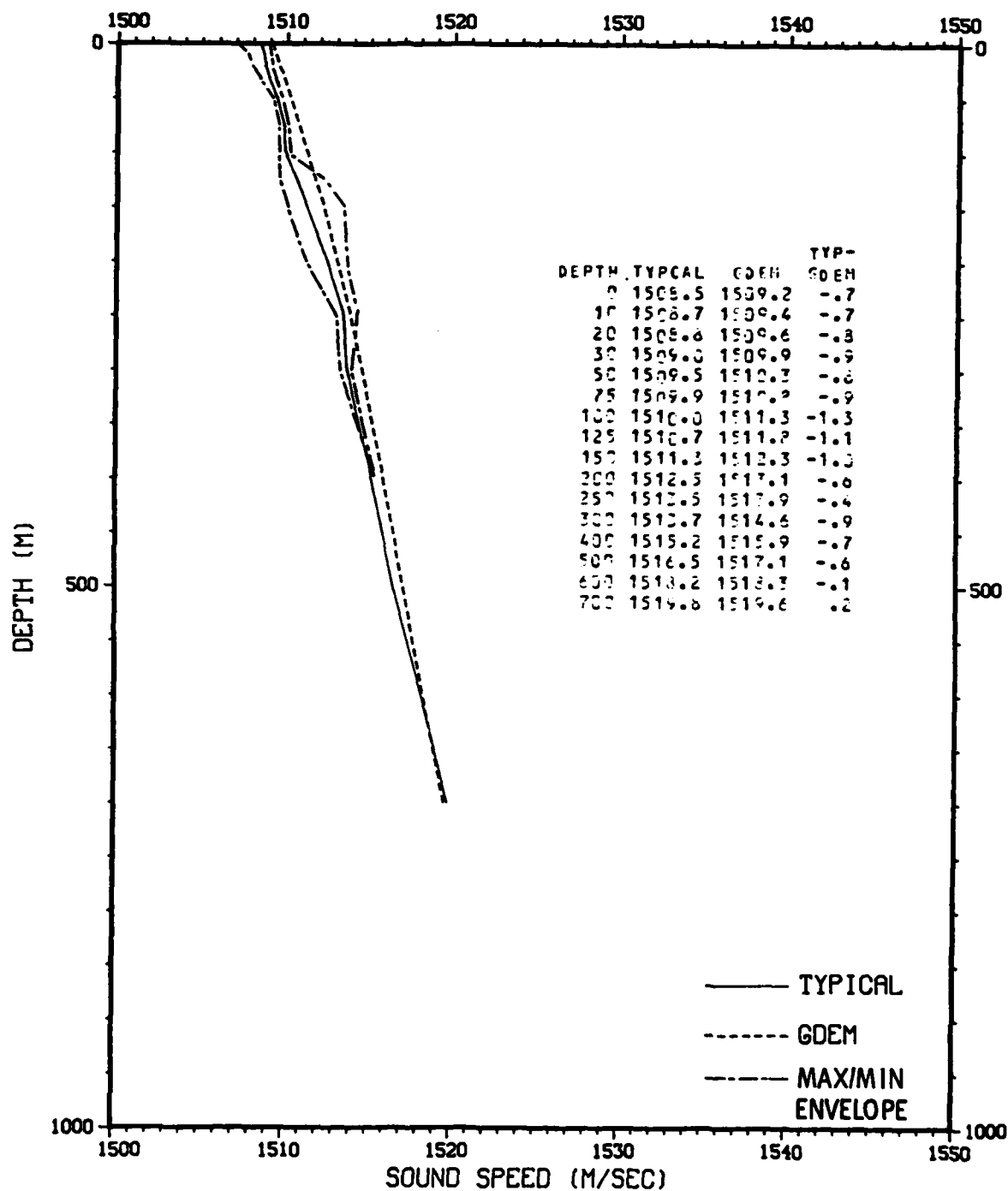


FIG. 5-9. VERTICAL SOUND-SPEED PROFILE FOR STRAIT OF SICILY (JAN - MAR)

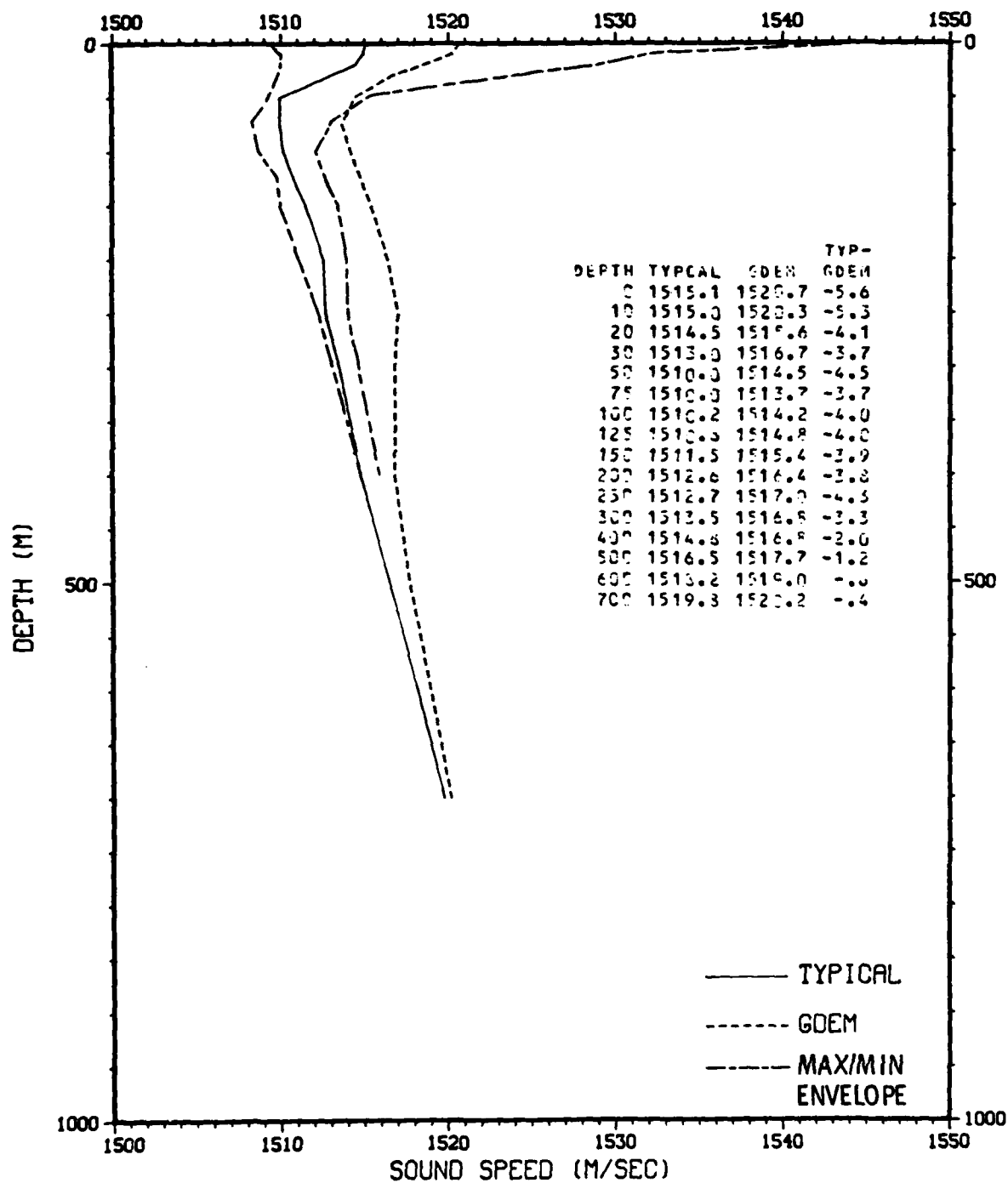


FIG. 5-10. VERTICAL SOUND-SPEED PROFILE FOR STRAIT OF SICILY (APR - JUN)

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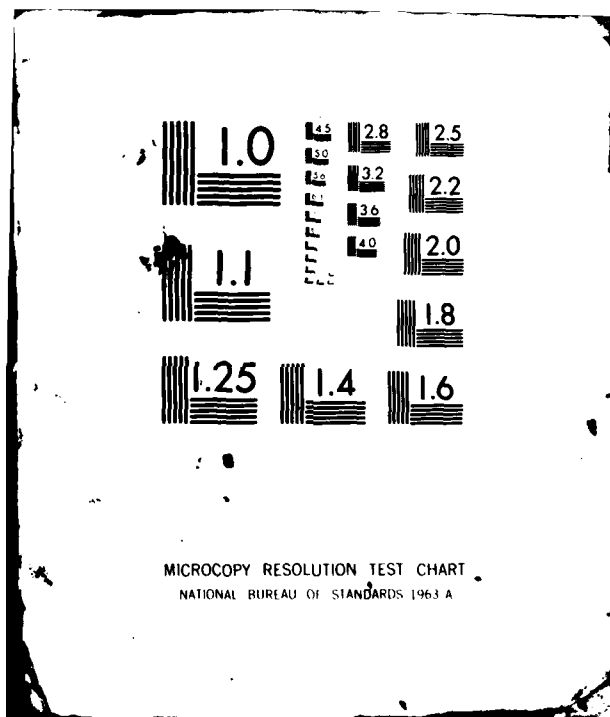
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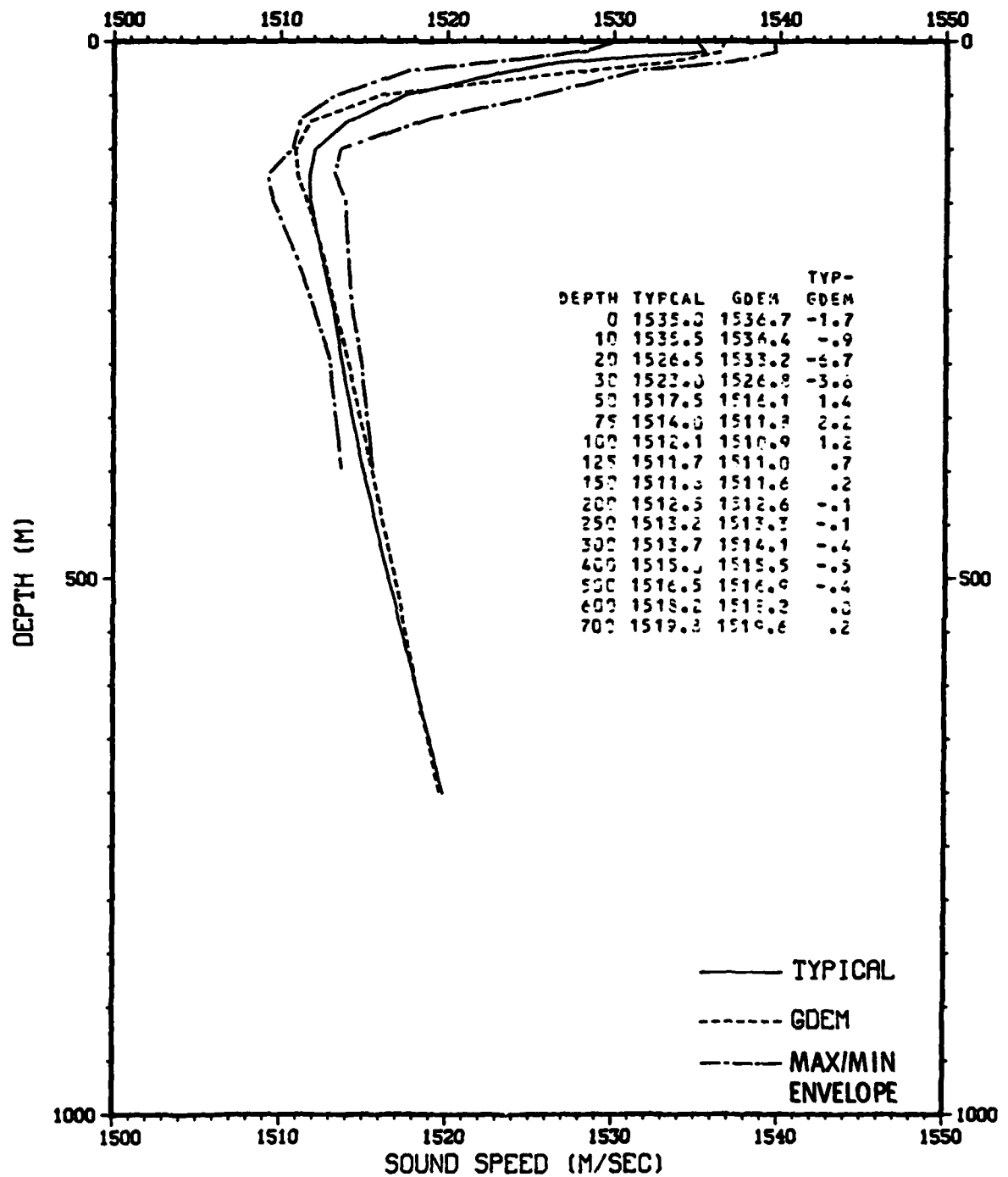


FIG. 5-11. VERTICAL SOUND-SPEED PROFILE FOR STRAIT OF SICILY (JUL - SEP)

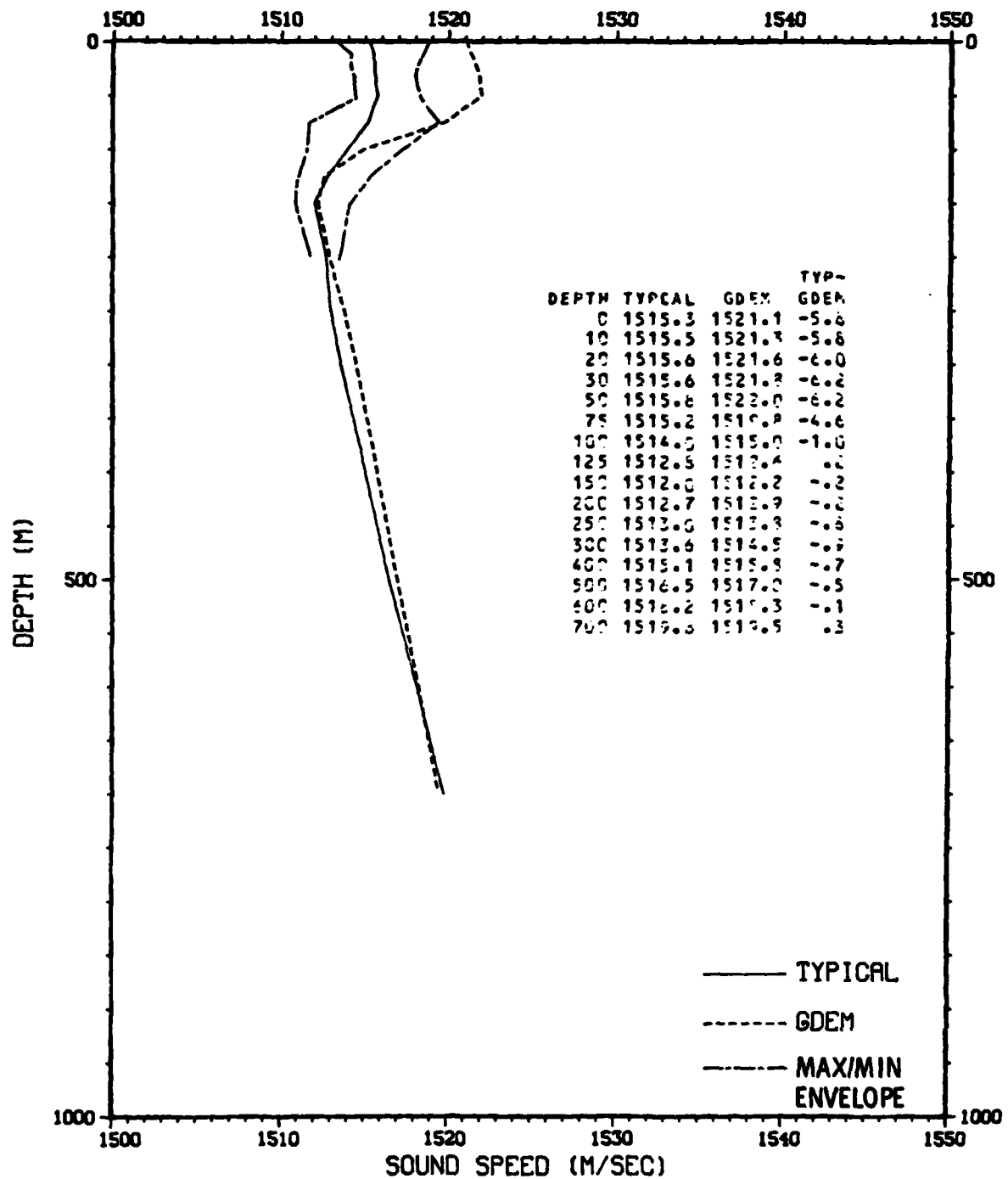


FIG. 5-12. VERTICAL SOUND-SPEED PROFILE FOR STRAIT OF SICILY (OCT - DEC)

## 6.0 VERTICAL TEMPERATURE, SALINITY, AND SOUND-SPEED PROFILE COMPARISONS FOR MEDITERRANEAN (MED) LOCATION #5

Twelve vertical comparisons of temperature (T), salinity (S), and sound-speed (SS) for winter, spring, summer, and fall seasons are presented in this section.

### 6.1 Description

Med Location #5 is taken from the Ionian Sea region of the Mediterranean Sea. The geographic location selected for this comparison is at  $35^{\circ}00'$  north latitude and  $018^{\circ}00'$  east longitude. Vertical temperature, salinity, and sound-speed profiles of seasonal comparisons are shown in Figures 6-1 through 6-12.

The Ionian Sea region of the Mediterranean Sea, depicted as Region E in Figure 1-1, is defined for this report as the body of water that is bounded to the west by  $15^{\circ}$  east longitude; to the north by the land masses of Sicily, Italy,  $40^{\circ}$  north latitude and Greece; to the east by  $22^{\circ}$  east longitude; and to the south by  $33^{\circ}$  north latitude.

Meteorologically, this region is considered variable and seasonally active. The seasonal patterns are controlled primarily by the monsoonal characteristics of the Sahara Desert to the south and the Eurasian land mass to the north. The winters are characterized by a dominant high pressure with associated unsettled, windy conditions. The summers are characterized by a relatively weak high pressure with associated warm, dry settled conditions and light winds. Cyclogenesis does occur over the Ionian Sea with their origin in the Atlas Mountains of Algeria and Tunisia, the primary path for the North African cyclones is north-eastward across the Ionian Sea. A secondary zone for Ionian cyclogenesis is located over the northern portion of the Ionian Sea. This region is known to generate southeastward cyclones that are associated with the southerly invasion of cold-air-mass movements from the Adriatic Sea.

Oceanographically, this region is considered variable. The ocean variability and changes in the near-surface vertical water column are directly influenced by the impulses received from the paths of cyclogenesis through mechanical mixing (especially in the winter and early spring). Because of the seasonal influence of surface air masses from the Sahara Desert, this area will reflect wide variability in vertical surface and near-surface stratification, especially in salinity.

## 6.2 Comparisons for Location #5

The vertical site comparisons of seasonal temperature, salinity, and sound-speed profiles, respectively, are presented for Med Location #5.

- Temperature:

The January-to-March temperature envelope could not be developed from the statistical summaries because of an insufficient number of adequate data samples (Figure 6-1). There was only one usable observation for this location. The GDEM value at the surface differs from the single observation by only  $0.76^{\circ}\text{C}$ . Below 150 m, the GDEM and the single observation reflect very close agreement.

The April-to-June temperature envelope taken from the statistical summaries was based on a data sample size of 42 observations (Figure 6-2). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only  $0.14^{\circ}\text{C}$ . The numerical values within the thermocline region of GDEM range as high as  $1.73^{\circ}\text{C}$ . There is a slight negative inflection at 250 m not reflected by GDEM. Below 250 m, there is close agreement (of  $0.01^{\circ}\text{C}$  to  $0.14^{\circ}\text{C}$ ) between GDEM and the typical.

The July-to-September temperature envelope taken from the statistical summaries was based on a data sample size of 12 observations (Figure 6-3). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by  $0.34^{\circ}\text{C}$ . Between 50 to 400 m, the differences between GDEM and the typical range between  $1.09^{\circ}\text{C}$  and  $0.18^{\circ}\text{C}$ . Below 400 m, there is close agreement (of less than  $0.36^{\circ}\text{C}$ ) between GDEM and the typical.

The October-to-December temperature envelope could not be developed from the statistical summaries because of an insufficient number of adequate data samples (Figure 6-4). There was



only one usable observation for this location. The GDEM value at the surface differs from the typical by only  $0.03^{\circ}\text{C}$ . Close agreement exists between the surface and 30 m. Differences greater than  $1.0^{\circ}\text{C}$  ( $3.56^{\circ}\text{C}$  and  $1.60^{\circ}\text{C}$ ) occur at the 50 m and 75 m levels, respectively. Below 75 m, all differences are small (less than  $0.47^{\circ}\text{C}$ ), thus reflecting very close agreement.

- Salinity:

The January-to-March salinity envelope could not be developed from the statistical summaries because of an insufficient number of adequate data samples (Figure 6-5). There was only one usable observation for this location. The GDEM value at the surface differs from the single observation by only 0.12 ppt. Below the surface, down to 3000 m, the GDEM values do not differ by more than 0.16 ppt.

The April-to-June salinity envelope taken from the statistical summaries was based on 42 observations (Figure 6-6). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by 0.54 ppt. Below the surface to 125 m, the numerical differences are between 0.39 ppt and 0.63 ppt. Below 250 m, the differences are slight (less than 0.18 ppt) reflecting a slightly lower GDEM value.

The July-to-September salinity envelope taken from the statistical summaries was based on a data sample size of 12 observations (Figure 6-7). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.34 ppt. Below the surface to 3000 m, GDEM values do not differ from the typical by more than 0.13 ppt.

The October-to-December salinity envelope could not be developed from the statistical summaries because of an insufficient number of adequate data samples (Figure 6-8). There was only one usable observation for this location. The GDEM value at the surface differs from the typical by only 0.08 ppt. This narrow difference continues down to 30 m. At the 50 and 75 m levels, the differences are 0.41 ppt and 0.20 ppt, respectively. Below 100 m to 3000 m, the numerical differences do not exceed 0.18 ppt reflecting a slightly lower GDEM value.

- Sound Speed:

The January-to-March sound-speed envelope could not be developed from the statistical summaries because of an insufficient number of adequate data samples (Figure 6-9). There was only one usable observation for this location. The GDEM value at the

surface differs from the single observation by 2.3 m/s. Below the surface and down to 100 m, the differences range between 1.1 m/s and 2.2 m/s. Below 200 m and down to 3000 m, the maximum difference is 0.4 m/s.

The April-to-June sound-speed envelope taken from the statistical summaries was based on a data sample size of 42 observations (Figure 6-10). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by 0.2 m/s. With the exception of the 20 m, 30 m, and 50 m, levels (with differences of 4.3 m/s, 2.0 m/s, and 1.1 m/s, respectively), the maximum difference below 300 m does not exceed 0.3 m/s.

The July-to-September sound-speed envelope taken from the statistical summaries was based on a data sample size of 12 observations (Figure 6-11). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by 1.0 m/s. Differences in value of 1.2 m/s to 3.6 m/s exist between 20 m and 75 m. Differences in value of 1.1 m/s to 2.5 m/s exist between 150 m and 500 m. Below 600 m, the maximum difference is 0.5 m/s.

The October-to-December sound-speed envelope could not be developed from the statistical summaries because of an insufficient number of adequate data samples (Figure 6-12). There was only one usable observation for this location. The GDEM value at the surface does not differ from the single observation. Differences in value of 10.8 m/s and 5.1 m/s exist at 50 m and at 75 m, respectively. Below the surface down to 30 m, and from 200 m down to 3000 m, the maximum difference is 0.9 m/s.

### 6.3 Evaluation - Ionian Sea (Location #5)

- January to March:

An evaluation of the GDEM and typical temperature profile comparison reveals very close similarities in the thermal structure. The surface values differ by less than a degree ( $0.76^{\circ}\text{C}$ ). The mixed-layer depths differ by approximately 170 m. The differences in sea surface temperatures and layer depths are both realistic and acceptable ranges for this season and location. Below 125 m, the profiles are nearly identical. The primary difference between the two profiles are in the numerical depths for the mixed layer. Due to an insufficient number of adequate data samples (only one usable observation), an appropriate envelope could not be developed. The GDEM appears to adequately reflect a reasonable seasonally averaged winter temperature structure for this variable ocean region.

An evaluation of the GDEM and typical salinity profile comparison reveals general similar salinity structures. The major noticeable difference is that the typical has a distinct isohaline layer at the near-surface whereas the GDEM reflects a nonlayer profile. The GDEM has a definite positive gradient. Because of an insufficient number of adequate data samples (only one usable observation), an appropriate envelope could not be developed. The GDEM values for salinity below 600 m may be increased by approximately 0.11 ppt. The GDEM appears to adequately reflect a reasonable seasonally averaged winter salinity structure for this variable ocean region.

An evaluation of the GDEM and typical sound-speed profile comparison reveals a close similarity below 200 m. Above 200 m, GDEM does not reflect as strong and well defined a surface duct as the typical; however, GDEM does reflect the general trend for the winter half channel. Due to an insufficient number of adequate data samples (only one usable observation) an appropriate envelope could not be developed. Despite the differences in the depth of the surface ducts, the GDEM does represent a known winter half channel sound-speed structure for this variable ocean region.

- April to June:

An evaluation of the GDEM typical temperature profile comparison reveals similarities in thermal structure. The envelope in the near-surface is adequately wide indicating a variable spring structuring, and reflecting a zone of sufficient thermal variability. GDEM appears to reflect and represent a reasonable seasonally averaged spring thermal structure for this variable ocean region when compared with the 42 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals slight similarities in haline structure. The surface and near-surface characteristics indicate differences. These differences are in surface value and in halocline gradient. Both, however, remain within the envelope. The typical appears to be reflecting the upper end of the values. The GDEM values for salinity below 700 m may perhaps be increased by approximately 0.11 ppt. GDEM appears to reflect a reasonable seasonally averaged spring haline structure for this variable ocean region when compared with the 42 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals general similarities in overall trend. The sound-channel axes are similarly shallow. The gradients of the sonoclines are similar. The GDEM sound-speed profile appears to reflect a reasonable seasonally averaged spring sound-speed structure for this variable ocean region when compared with the 42 usable observations.

- July to September:

An evaluation of the GDEM and typical temperature profile comparison reveals some similarity in thermal structure. The near-surface thermocline gradients (above 50 m) are nearly identical. Differences in thermal structure development appear between 50 m and down to approximately 400 m. The GDEM profile indicates a sharp gradient change at approximately 75 m, then toward isothermal to 200 m, whereas the typical gradually decreases. In reviewing the data set, the typical was taken in July (early in the season) and therefore reflects to some degree the minimum end of the envelope. Both are reasonable for this time period. GDEM appears to reflect more of the mean within the envelope of observed values. The envelope is substantially wide even below 200 m and down to 700 m, which indicates a very pronounced variability within this season over the observational time period. Several of the observations reveal near isothermal structure between 100 to 200 m. GDEM appears to reflect and represent a reasonable seasonally averaged summer thermal structure for this variable ocean region when compared with the 12 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals general similarities in trend of the haline structures. The GDEM near surface does not reflect a negative structuring as indicated by the typical or the envelope. GDEM reveals a positive gradient. This can result from the near-surface averaging process of GDEM. Below 500 m, GDEM values are slightly lower (only 0.07 ppt) than the minimum of the envelope. The positive gradient in the near surface and the slightly lower values below 500 m are not considered significant negative features. GDEM appears to reflect an acceptable seasonally averaged summer haline structure for this variable ocean region when compared with the 12 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals some similarities. The gradient of the sonoclines is very similar above 50 m and the profiles are similar below 700 m. There are differences in the depths of the GDEM and typical sound channel axis of approximately 75 m. The gradients immediately below the primary axis (between 150 and 250 m), are also different. The GDEM summer sound-speed profile is considered seasonally representative for this variable ocean region when compared with the 12 usable observations.

- October to December:

An evaluation of the GDEM and typical temperature profile comparison reveals some similarities in thermal structure. The

similarities are in surface values and in values found below approximately 200 m. Slight differences exist in the upper gradient of the thermoclines. The primary difference is in the depth of the thermoclines. This difference is approximately a 20 m separation. A 20 m thermocline separation is not considered a substantial difference for this ocean region, especially when the transitional time period is fall. Variations in the depth of the thermocline are to be anticipated for this particular region during fall thermal restructuring. Due to an insufficient number of adequate data samples (only one usable observation) an appropriate envelope could not be developed. The GDEM appears to reflect a reasonable seasonally averaged fall thermal structure for this variable ocean region.

An evaluation of the GDEM and typical salinity profile comparison reveals little similarity in haline structure. The near-surface structure is different. GDEM reveals a zero layer structure; but the typical reveals a surface haline layer of approximately 30 m in depth. Below the haline layer the typical has a definite and well-defined negative halocline with a salinity minimum at approximately 50 m. Based on one observation, below this salinity minimum the halocline reverses to positive down to 500 m. On the other hand, GDEM lacks a layer, does not change in gradient direction, and has a near surface salinity minimum at the surface. Differences also exist in the depth of the salinity maximums. GDEM has a salinity maximum at approximately 250 m. The salinity maximum of the typical is at approximately 350 m. Below their respective primary salinity maximums, GDEM reveals a stronger negative gradient, which results in a difference in numerical value of between approximately 0.11 ppt and 0.17 ppt to those of the typical down to 2000 m. The GDEM values for salinity may perhaps be increased by 0.15 ppt below 400 m down to 3000 m. Due to an insufficient number of adequate data samples (only one usable observation) an appropriate envelope could not be developed. Modification of the GDEM fall salinity profile is viewed as appropriate.

An evaluation of the GDEM and typical sound-speed profile comparison reveals some similarities. These similarities are primarily in the gradient of the sonoclines above the primary sound-channel axis and in the gradients below 500 m down to 3000 m. The noticeable differences are the numerical values for sound speed at the primary sound channel axis (GDEM - 1515.7 m/s; typical - 1513.2 m/s), the gradients of the sound-speed profiles immediately below the primary sound channel axis, and the presence of a weak secondary sound channel axis at approximately 300 m (in GDEM only). Because of an insufficient number of adequate data samples

(only one usable observation), an appropriate envelope could not be developed. The difference in the numerical values of sound speed at and near the primary sound channel axis is, in part, due to the cumulative effects of the features revealed in both the temperature and salinity profiles. The weak secondary sound channel of GDEM appears to be influenced sufficiently by the noticeable reversal in the salinity gradient at those depths. In reviewing other supplemental data sets for this time period and location, the weak secondary sound channel occurs approximately 10 to 15 percent of the time. Therefore, although a real intermittent feature, it is considered neither a seasonally nor historically persistent representative feature for this evaluation and location.

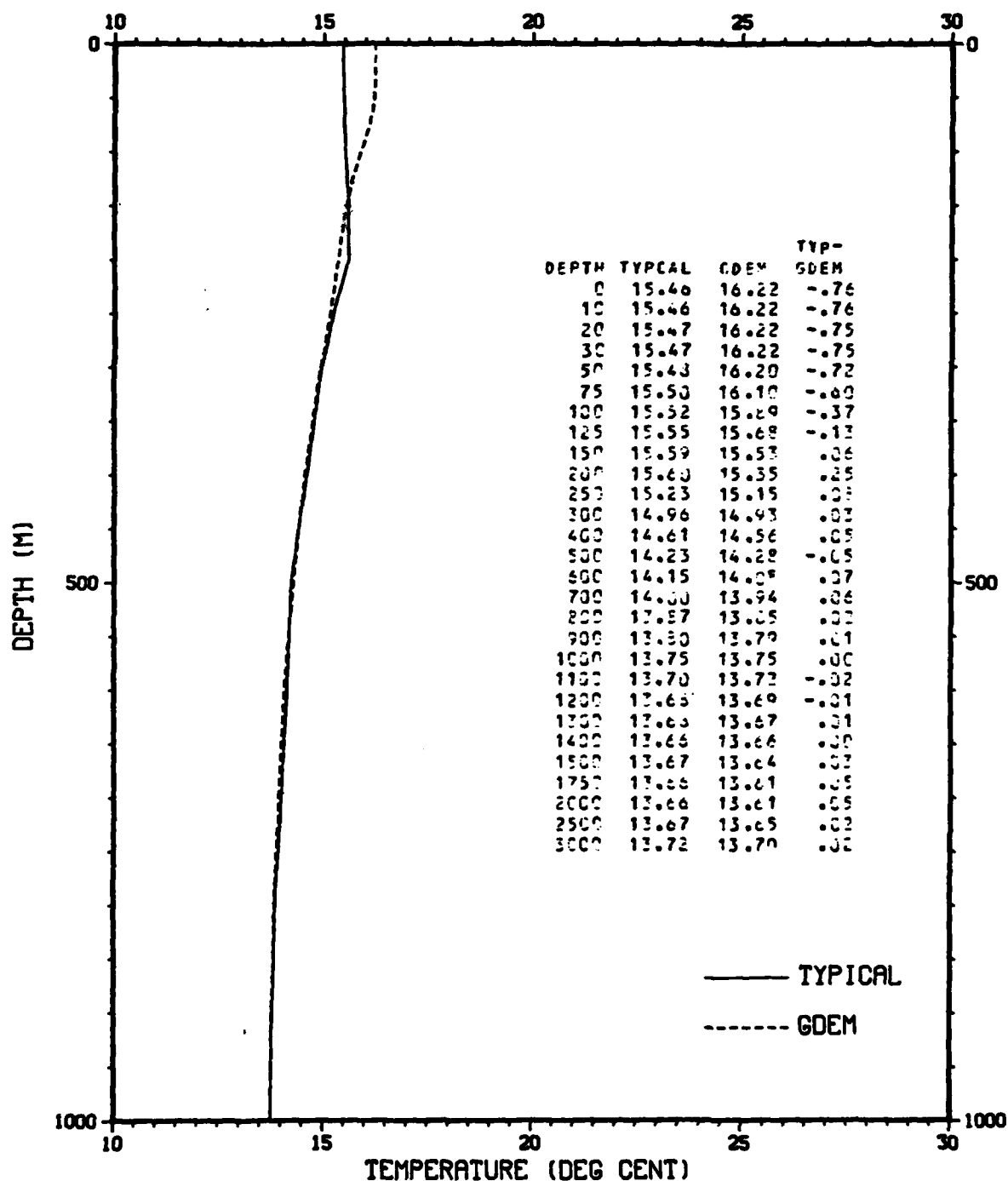


FIG. 6-1. VERTICAL TEMPERATURE PROFILE FOR IONIAN SEA (JAN - MAR)

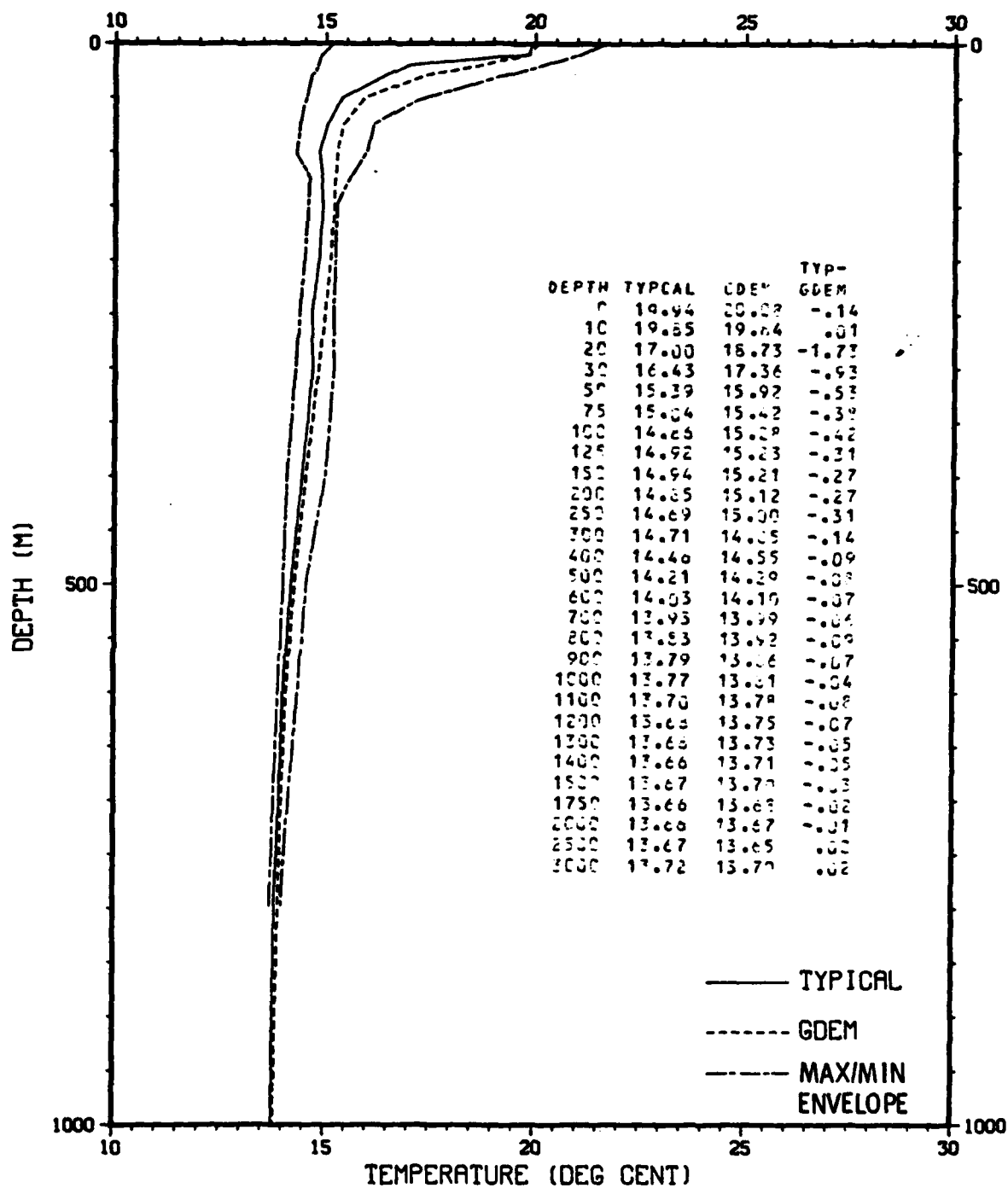


FIG. 6-2. VERTICAL TEMPERATURE PROFILE FOR IONIAN SEA (APR - JUN)



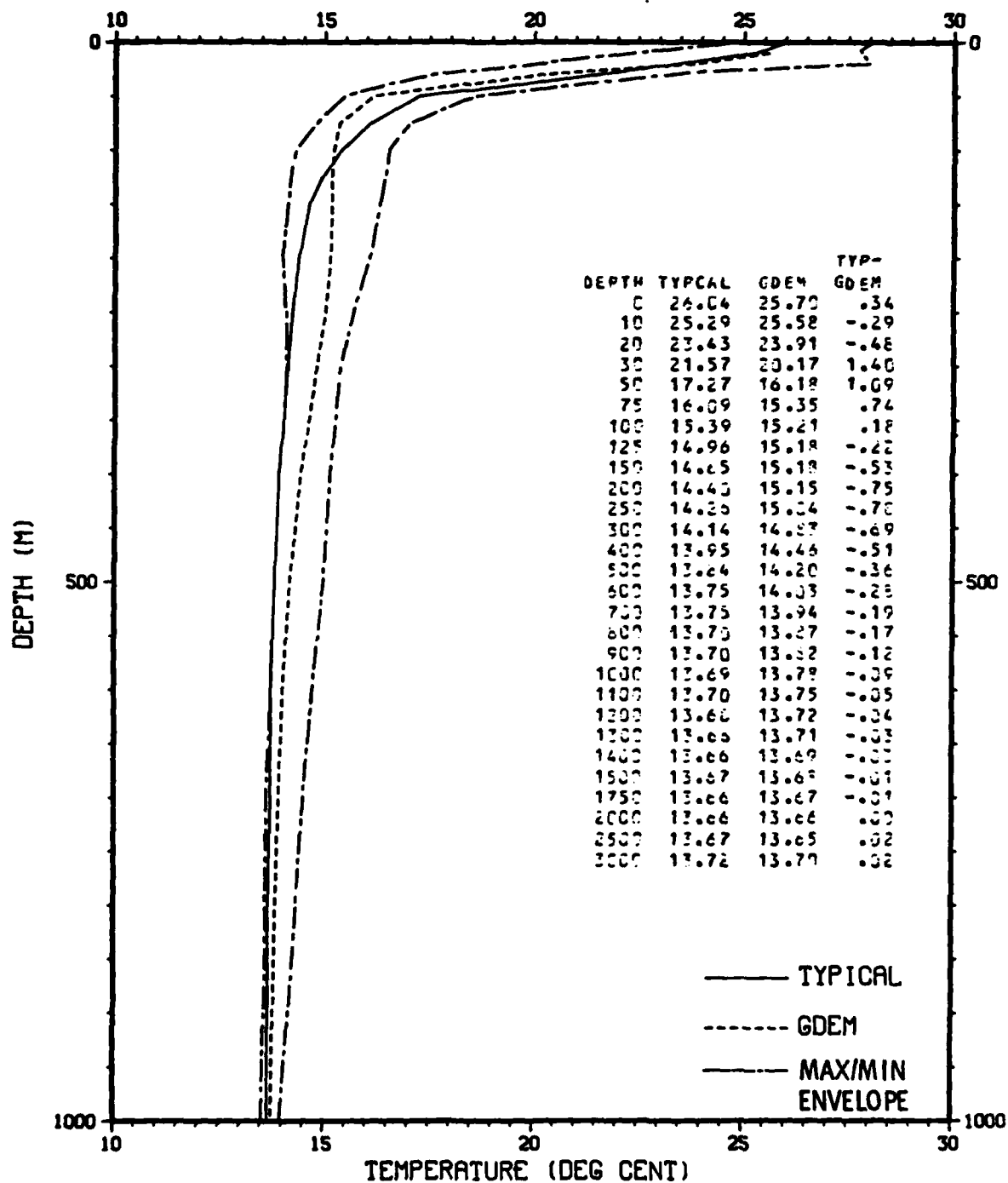


FIG. 6-3. VERTICAL TEMPERATURE PROFILE FOR IONIAN SEA (JUL - SEP)

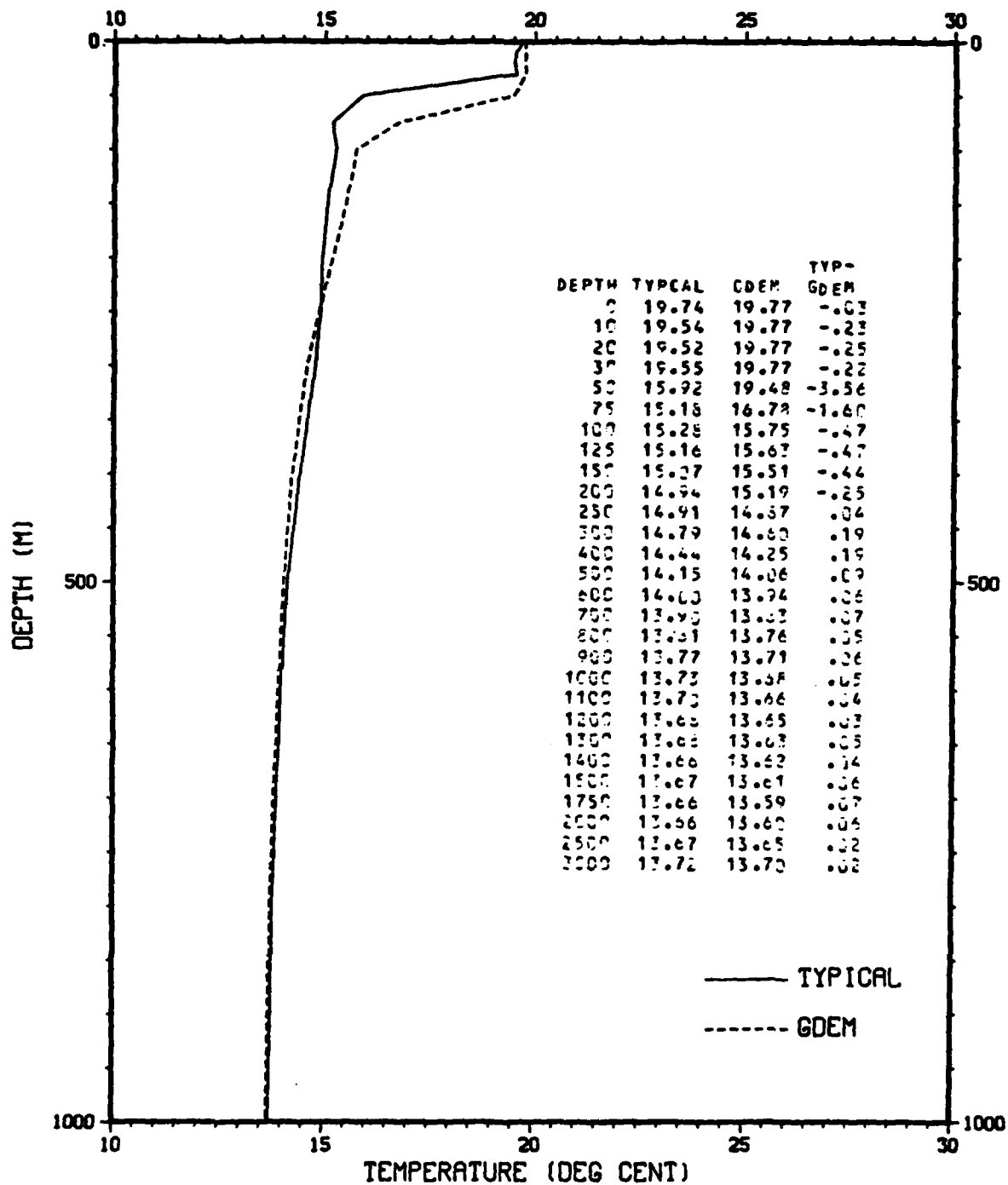


FIG. 6-4. VERTICAL TEMPERATURE PROFILE FOR IONIAN SEA (OCT - DEC)

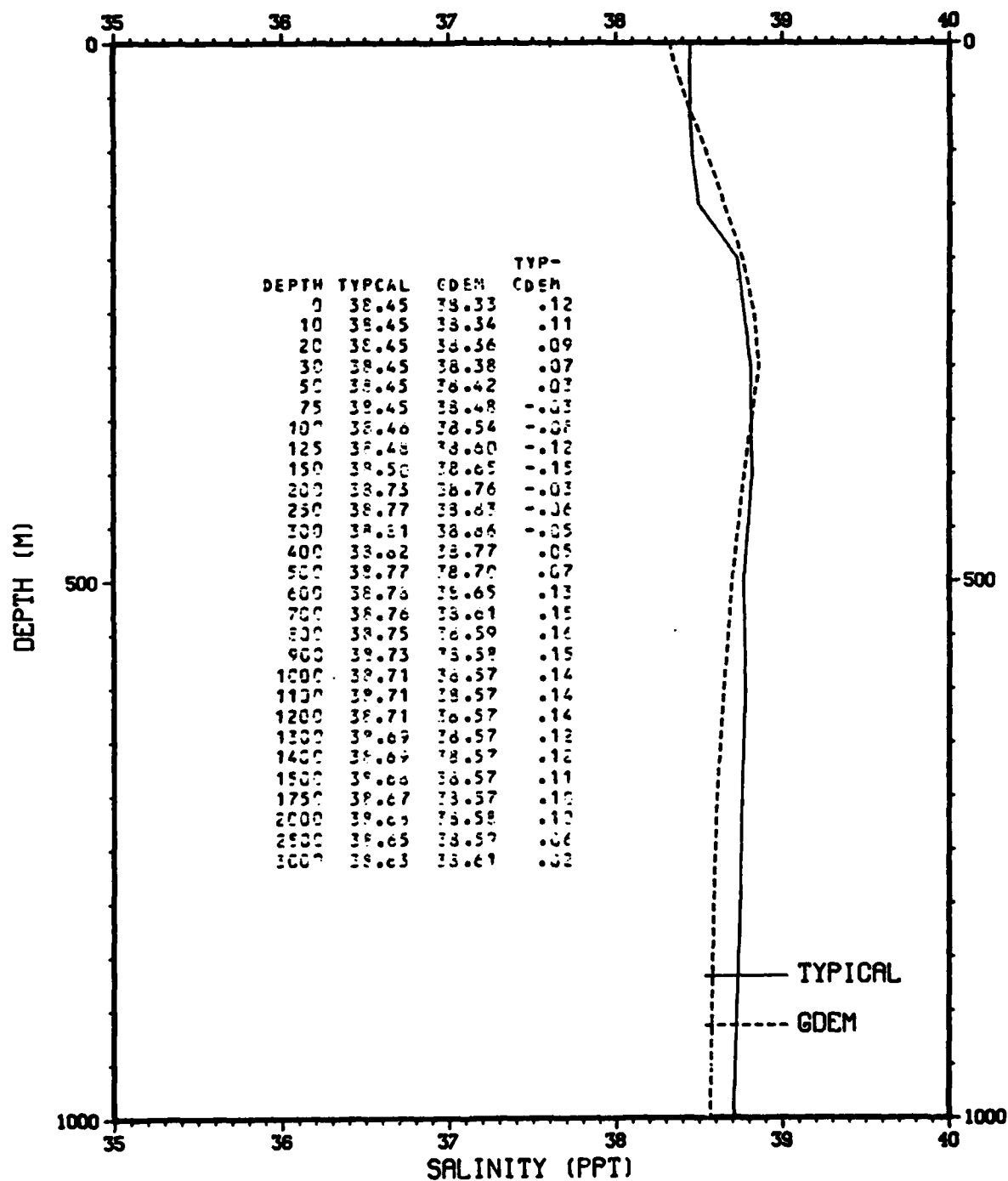


FIG. 6-5. VERTICAL SALINITY PROFILE FOR IONIAN SEA (JAN - MAR)

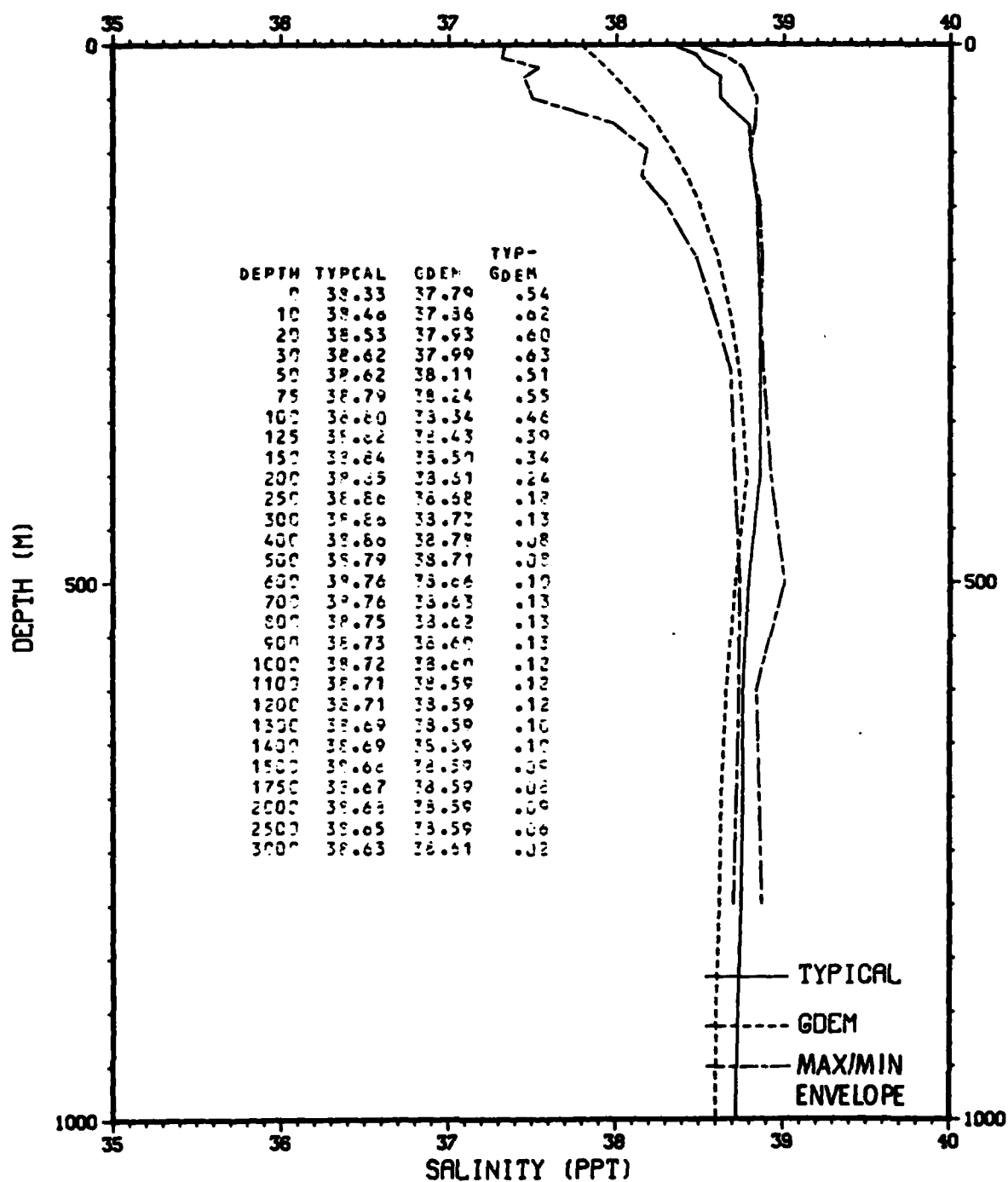


FIG. 6-6. VERTICAL SALINITY PROFILE FOR IONIAN SEA (APR - JUN)

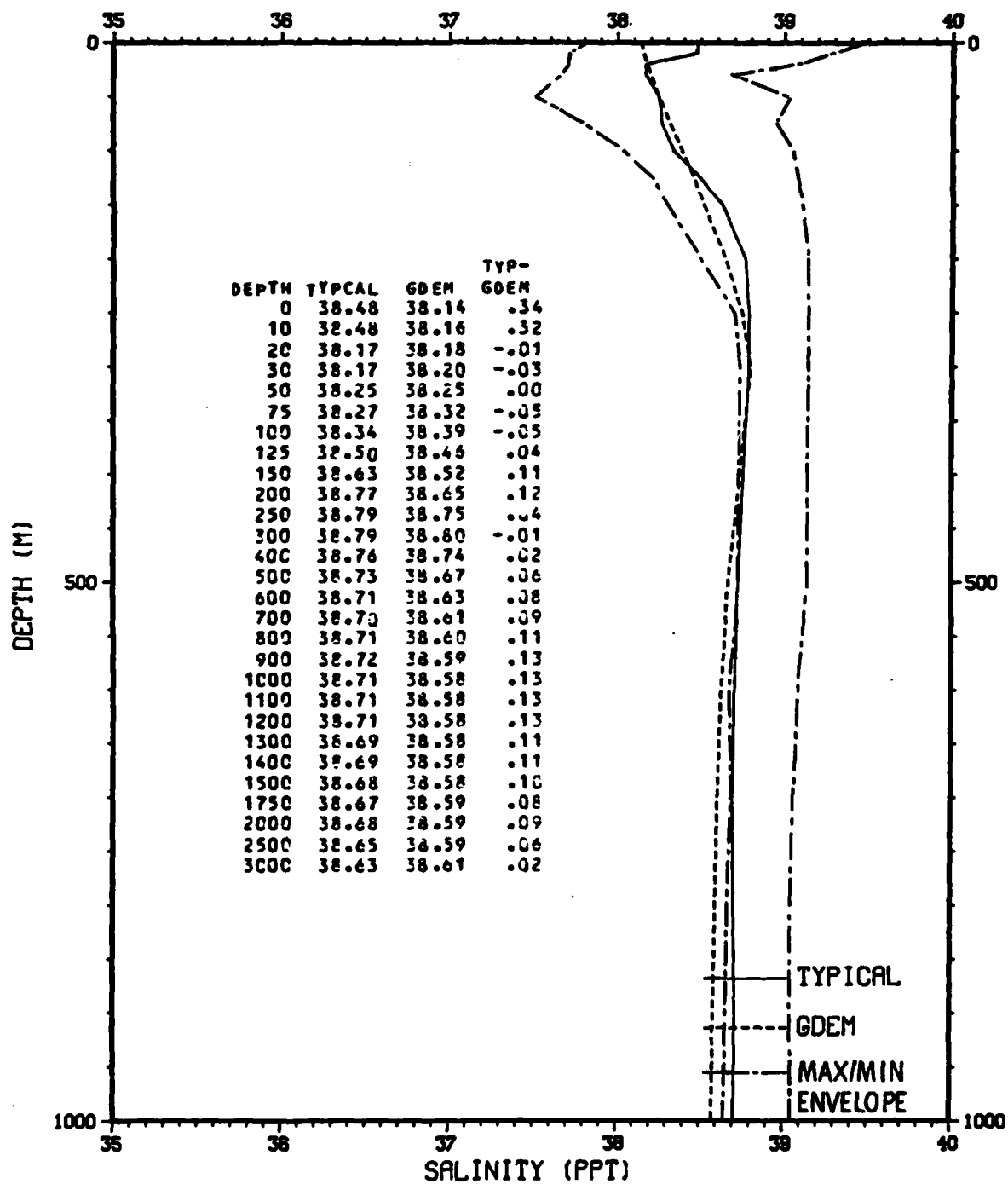


FIG. 6-7. VERTICAL SALINITY PROFILE FOR IONIAN SEA (JUL - SEP)

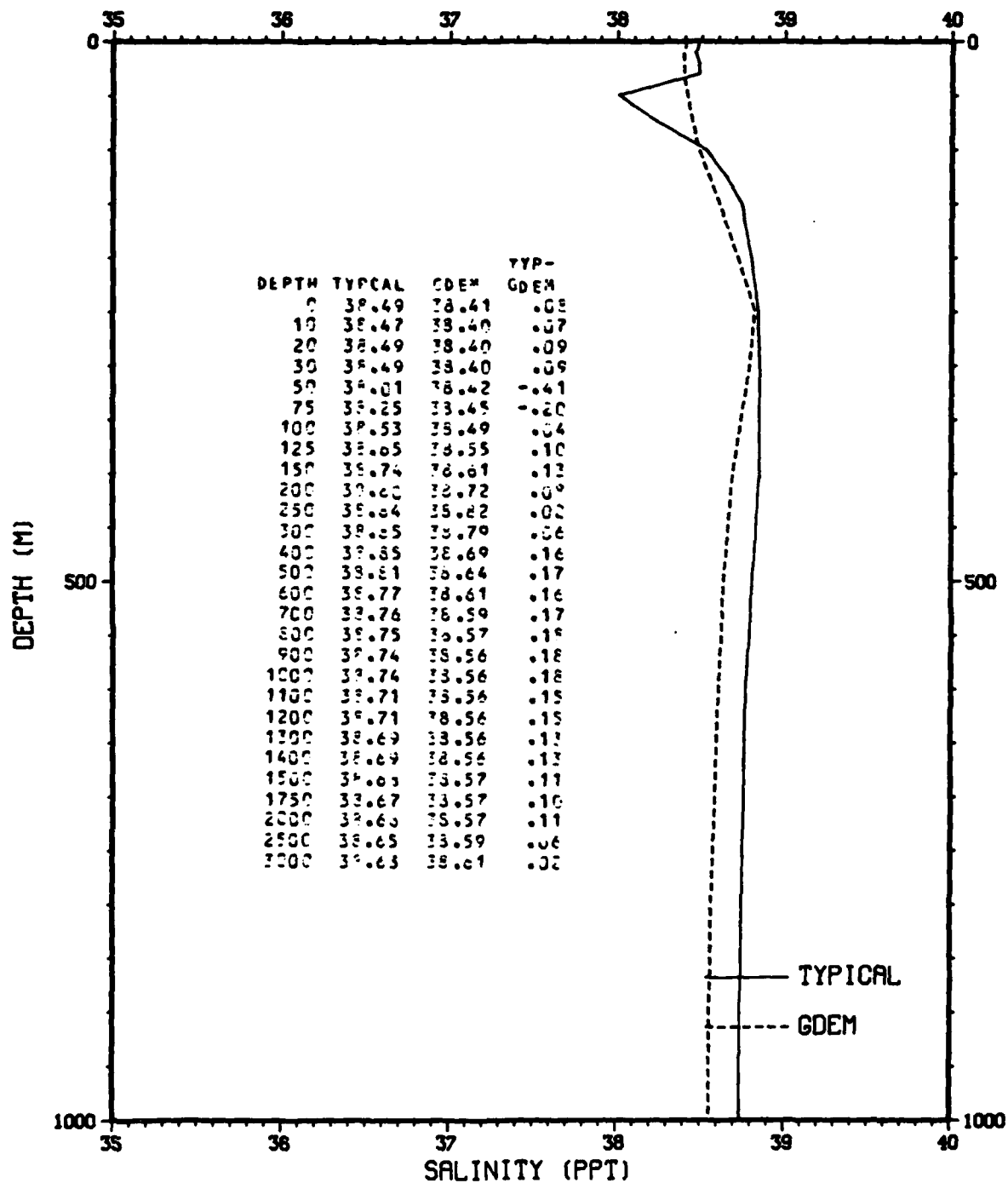


FIG. 6-8. VERTICAL SALINITY PROFILE FOR IONIAN SEA (OCT - DEC)

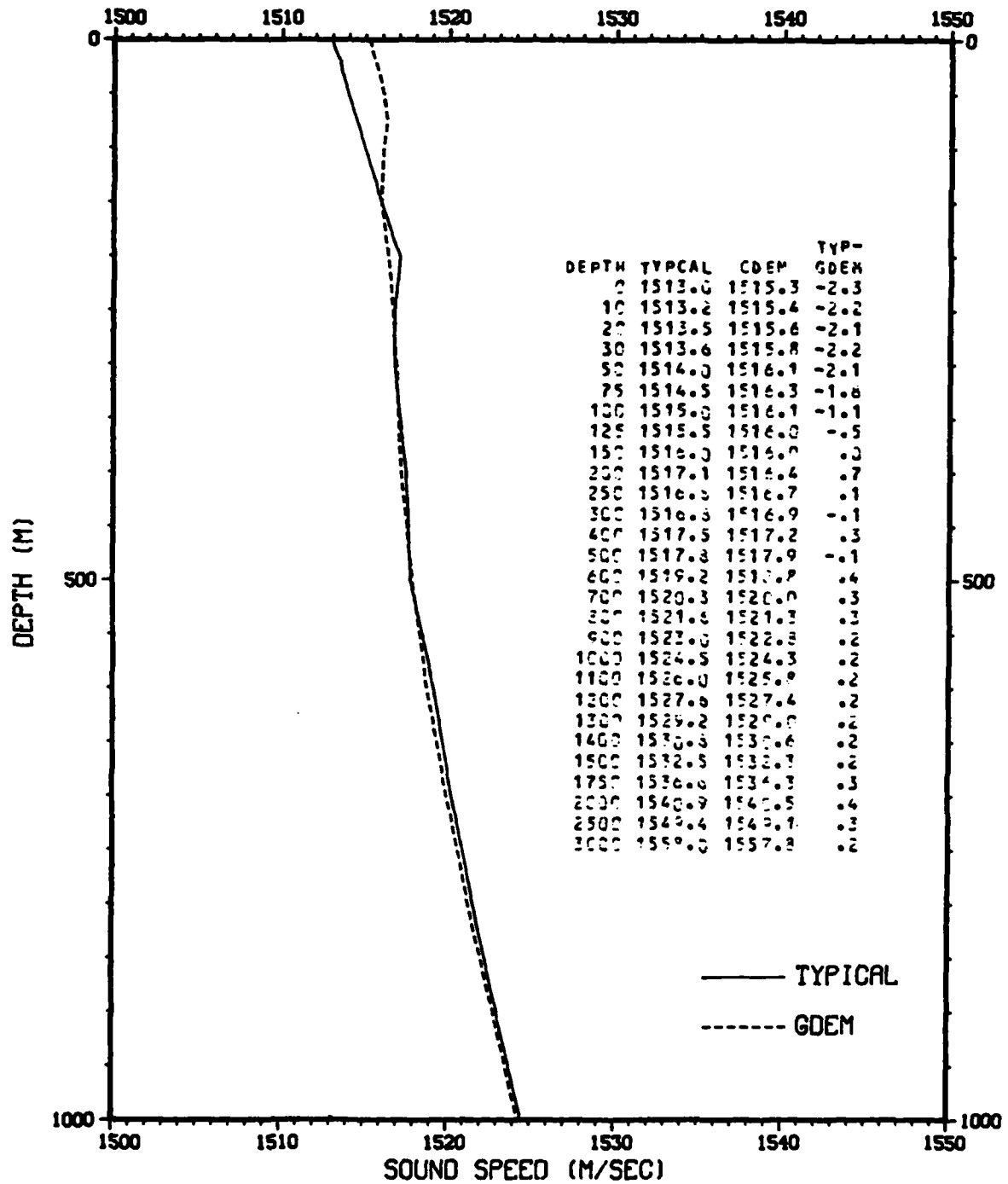


FIG. 6-9. VERTICAL SOUND-SPEED PROFILE FOR IONIAN SEA (JAN - MAR)

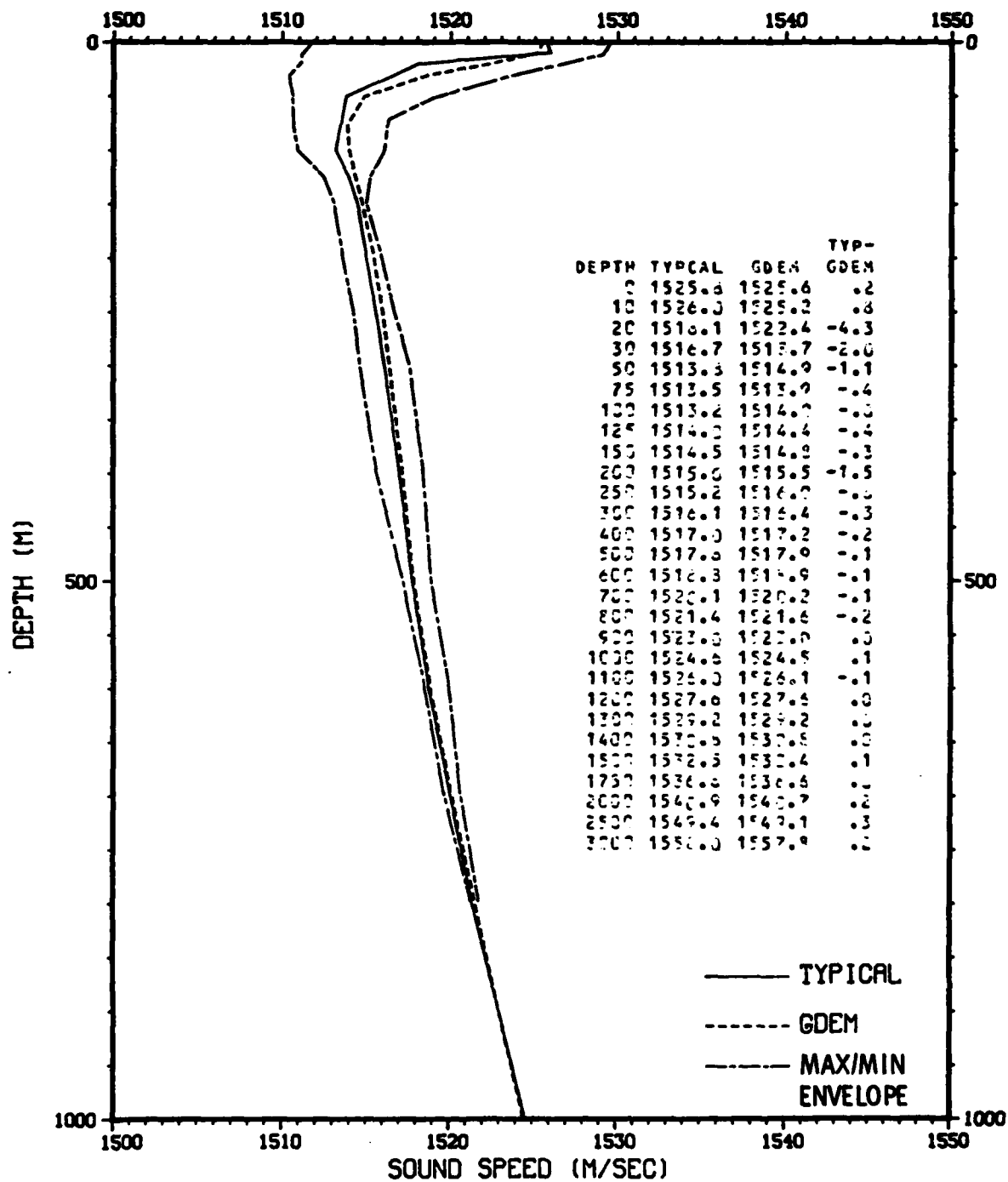


FIG. 6-10. VERTICAL SOUND-SPEED PROFILE FOR IONIAN SEA (APR - JUN)



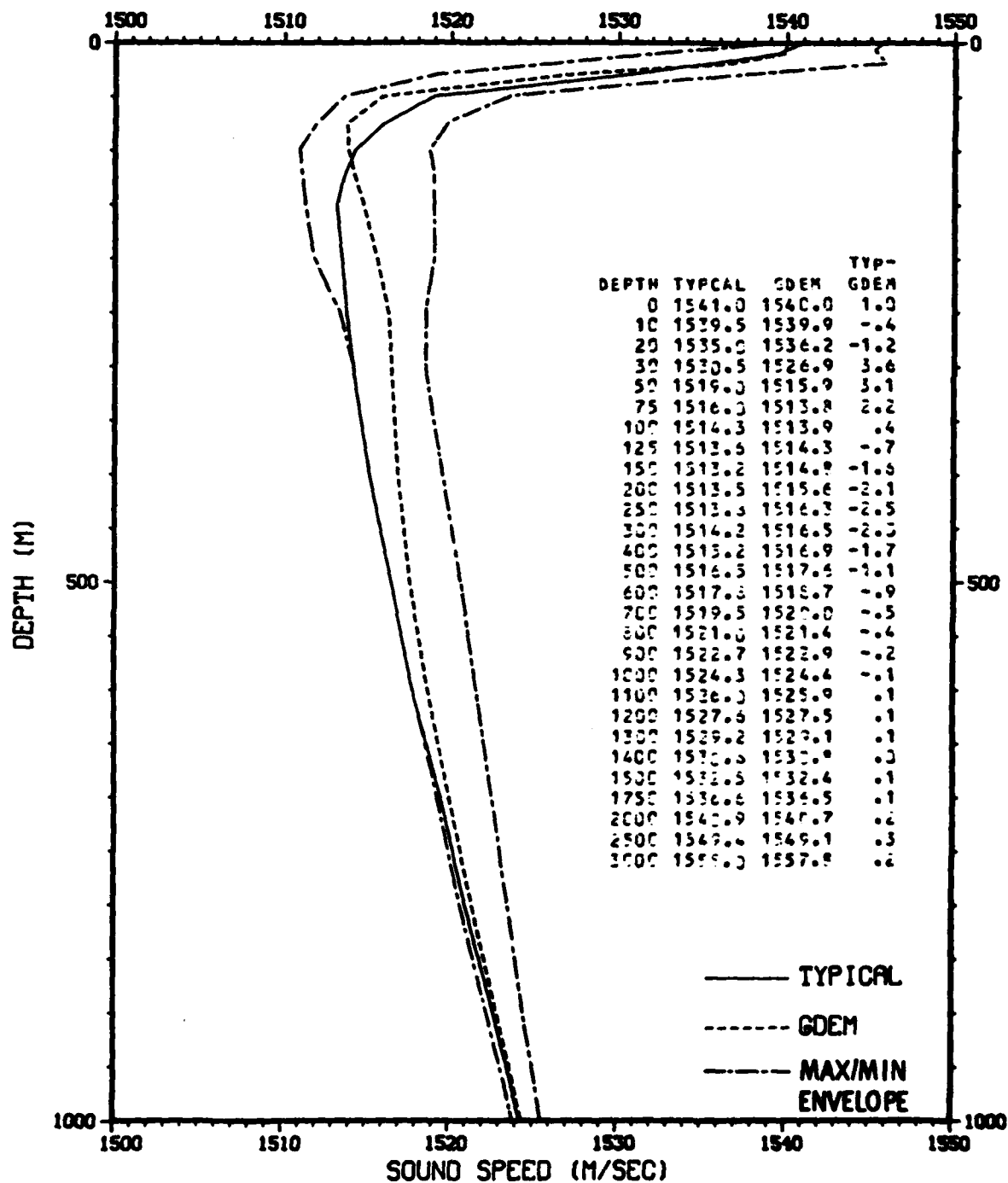


FIG. 6-11. VERTICAL SOUND-SPEED PROFILE FOR IONIAN SEA (JUL - SEP)

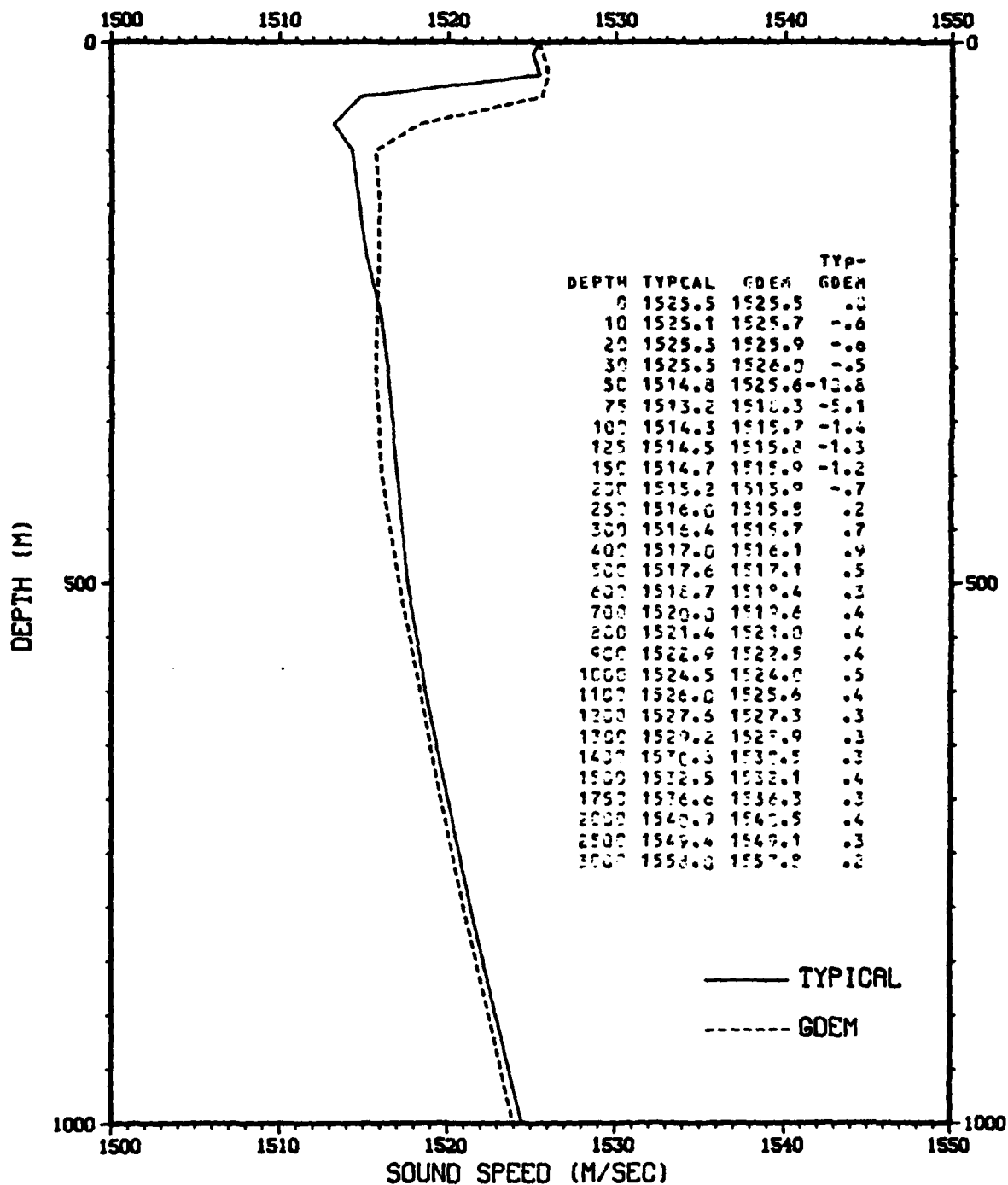


FIG. 6-12. VERTICAL SOUND-SPEED PROFILE FOR IONIAN SEA (OCT - DEC)

## 7.0 VERTICAL TEMPERATURE, SALINITY, AND SOUND-SPEED PROFILE COMPARISONS FOR MEDITERRANEAN (MED) LOCATION #6

Twelve vertical comparisons of temperature (T), salinity (S), and sound-speed (SS) for winter, spring, summer, and fall seasons are presented in this section.

### 7.1 Description

Med Location #6 is taken from the Levantine Sea region of the Mediterranean Sea. The geographical location selected for this comparison is at 33°00' north latitude and 030°00' east longitude. Vertical temperature, salinity, and sound-speed profiles of seasonal comparisons are shown in Figures 7-1 through 7-12.

The Levantine Sea region of the Mediterranean Sea, depicted as Region F on Figure 1-1, is located on the most easterly portion of the major eastern basin and is defined for this report as the body of water bounded to the west by 25° east longitude; to the north by the coastline of Turkey; to the east by the coastlines of Syria, Lebanon, and Israel; and to the south by the coastline of the United Arab Republic.

Meteorologically, this region is considered variable. Seasonal weather patterns are largely influenced by patterns that develop over the adjacent land masses. Cyclogenesis development, in general, is limited and originates at other distant regions (i.e. Ionian Sea and the Aegean Sea regions). A minor region is located over Cyprus. The winter patterns are very cold (relative to the sea surface temperatures), unsettled, and have associated strong winds. The summer patterns are dry and with heated air masses having persistent surface winds.

Oceanographically, this region is considered to be active, variable and important to overall surface distribution of salt and heat fluxes of the eastern Mediterranean basin. Within this region, processes leading to the development of Levantine Intermediate Water, positive salt fluxes, selective near-surface stratifications from the Nile, and large-scale subsurface flow patterns (currents) are known to take place.

## 7.2 Comparisons for Location #6

The vertical site comparisons of seasonal temperature, salinity, and sound-speed profiles, respectively, are presented for Med Location #6.

- **Temperature:**

The January-to-March temperature envelope taken from the statistical summaries was based on a data sample size of 15 observations (Figure 7-1). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only  $0.45^{\circ}\text{C}$ . Differences in value of GDEM between the surface and 150 m are less than  $0.76^{\circ}\text{C}$  from the typical. Below 200 m, the differences are very slight (less than  $0.12^{\circ}\text{C}$ ) and reflect close agreement.

The April-to-June temperature envelope taken from the statistical summaries was based on a data sample size of 17 observations (Figure 7-2). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only  $0.77^{\circ}\text{C}$ . Differences in value of GDEM between the surface and 30 m vary up to  $1.14^{\circ}\text{C}$ ; however, below 30 m down to 500 m, the maximum difference is just  $0.79^{\circ}\text{C}$ , which occurs at 300 m. Below 500 m, the differences are very slight (less than  $0.18^{\circ}\text{C}$ ) and reflect close agreement.

The July-to-September temperature envelope taken from the statistical summaries was based on a data sample size of 29 observations (Figure 7-3). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by  $1.29^{\circ}\text{C}$ . Differences below the surface to 50 m do not exceed  $0.80^{\circ}\text{C}$ ; below 75 m the differences are very slight (less than  $0.37^{\circ}\text{C}$ ) and reflect close agreement.

The October-to-December temperature envelope taken from the statistical summaries was based on a data sample size of 14 observations (Figure 7-4). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only  $0.29^{\circ}\text{C}$ . Differences in value of GDEM between the surface and 50 m do not exceed  $0.33^{\circ}\text{C}$ . At 50 m there is a difference of  $1.98^{\circ}\text{C}$ . Below 75 m, the differences are very slight (less than  $0.34^{\circ}\text{C}$ ) and reflect close agreement.

- **Salinity:**

The January-to-March salinity envelope taken from the statistical summaries was based on a data sample size of 15 observations (Figure 7-5). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only

0.13 ppt. With the exception of the 10 m and 20 m levels (which have less than 0.19 ppt differences), the differences below 30 m are very slight and do not exceed 0.10 ppt.

The April-to-June salinity envelope taken from the statistical summaries was based on a data sample size of 17 observations (Figure 7-6). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.09 ppt. With the exception between the 10 m and 30 m levels (which have less than 0.17 ppt differences), the differences below 150 m are very slight and do not exceed 0.07 ppt.

The July-to-September salinity envelope taken from the statistical summaries was based on a data sample size of 29 observations (Figure 7-7). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.09 ppt. Between the 10 m and 125 m levels (with the exception of the 0.31 ppt difference at 75 m), GDEM differs from the typical by less than 0.17 ppt. Below 100 m, the differences are slight and do not exceed 0.13 ppt.

The October-to-December salinity envelope taken from the statistical summaries was based on a sample size of 14 observations (Figure 7-8). The GDEM value at the surface falls within the envelope of observations and differs from the typical by only 0.07 ppt. With the exception of differences of 0.11 ppt, 0.20 ppt, and 0.16 ppt occurring at the 30 m, 50 m, and 75 m levels, differences between GDEM and the typical do not exceed 0.08 ppt.

- Sound Speed:

The January-to-March sound-speed envelope taken from the statistical summaries was based on a data sample size of 15 observations (Figure 7-9). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by 1.2 m/s. Differences in value of 1.1 m/s to 2.1 m/s are found between the 30 m and 150 m levels. Below 150 m and down to 2000 m, the differences do not exceed 0.4 m/s.

The April-to-June sound-speed envelope taken from the statistical summaries was based on a data sample size of 17 observations (Figure 7-10). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by 2.0 m/s. Differences in value of 2.1 m/s to 3.4 m/s are found between the 10 m and 30 m levels. Differences in value of 1.0 m/s and 2.4 m/s are found between the 150 m and 500 m levels. Below 500 m and down to 2000 m the differences do not exceed 0.6 m/s.

The July-to-September sound-speed envelope taken from the statistical summaries was based on a data sample size of 29 observations (Figure 7-11). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by 3.0 m/s. With the exception of the 75 m (0.7 m/s) and the 100 m (0.9 m/s) levels, the differences in value below the surface and down to 250 m range between 1.0 m/s and 2.0 m/s. Below 250 m and down to 2000 m the differences do not exceed 0.6 m/s.

The October-to-December sound-speed envelope taken from the statistical summaries was based on a data sample size of 14 observations (Figure 7-12). The GDEM value at the surface falls well within the envelope of observed values and differs from the typical by only 0.8 m/s. With the exception of the 50 m and 75 m levels (which have differences of 5.4 m/s and 1.4 m/s, respectively), the differences in value below the surface and down to 500 m range between 0.5 m/s and 0.9 m/s. Below 500 m the differences do not exceed 0.1 m/s.

### 7.3 Evaluation - Levantine Sea (Location #6)

- January to March:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in thermal structure. Slight differences in numerical value (less than  $0.75^{\circ}\text{C}$ ) in the near surface are considered acceptable and realistic as reflected by the relatively wide envelope of winter variability. The thermal variability for this location is reasonable and extends substantially in depth to approximately 350 m. The GDEM and typical profiles are nearly identical in gradient and in numerical value below 200 m and down to 2000 m. The GDEM temperature profile appears to reflect a reasonable seasonally averaged winter thermal structure for this variable ocean region when compared with the 15 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals very close similarities in haline structure. With the exception of a few excursions, most of the differences are small. The general trend of a slight positive winter haline structure existing within a narrow salinity envelope of variability is most appropriate for this region in winter. The GDEM salinity profile appears to reflect a reasonable seasonally averaged winter haline structure for this variable ocean region when compared with the 15 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals acceptable similarities in sound-speed structure. The differences at the near-surface levels caused predominantly by the thermal structure are acceptable, and the variability of sound

speed within this near-surface layer is realistic for this location. The profiles below 200 m are nearly identical to each other down to 2000 m. The GDEM sound-speed profile appears to reflect a reasonable seasonally averaged winter sound-speed structure for this variable ocean region when compared with the 15 usable observations.

- April to June:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in thermal structure. With the exception at 20 m, the general trend of the overall profiles are in agreement, and the numerical values are within an acceptable range (less than 1.0°C). The envelope reflects a transitional variability process in the near surface. The maximum portion of the envelope above 200 m is relatively modest and could acceptably be wider for this period and region. The GDEM appears to reflect a reasonable seasonally averaged spring thermal structure for this variable ocean region when compared with the 17 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals general similarities in haline structure. The variability of salinity in the near surface is narrow and remains relatively well defined for this location in spring. GDEM does reflect this characteristic as it remains within the envelope. The GDEM appears to reflect a reasonable seasonally averaged spring haline structure for this variable ocean region when compared with the 17 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals some similarities. The typical reflects an active profile "in transition" when compared with the more seasonally averaged "late transition" profile. Both are reasonable. GDEM sound speeds appear noticeably higher between the 200 and 500 m levels for this season when compared with the other seasons for this location. GDEM reflects a late spring, mature transition sound-speed profile. GDEM appears to reflect a reasonable seasonally averaged spring sound-speed structure for this variable ocean region when compared with the 17 usable observations.

- July to September:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in thermal structure. Near-surface and lower-structure characteristics are nearly identical. The numerical values, as well as the gradients of the thermocline, are in very close agreement. Profile trend and characteristics below 300 m are also in very close agreement. Both the typical and the

GDEM have a slightly linear zone between 100 and 200 m. They are different numerically but are relatively parallel in orientation. With the exception of the flat linear region between 100 and 200 m, the general profile of GDEM appears to reflect a reasonable seasonally averaged summer thermal structure for this variable ocean region when compared with the 29 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals close similarities in haline structure below 200 m. GDEM reveals a reversal from negative to positive, then back to negative in its near-surface salinity profile. This substantial and known reversal in salinity for a seasonally averaged salinity profile for summer is considered to be remarkably reproduced by GDEM. Although there is generally an isohaline layer at the surface of about 20 m, there are near-surface seasonal summer haline reversals in gradient near this location of the basin. It is not an intermittent feature but one of frequent occurrence here in the summer period. GDEM appears to reflect a reasonable seasonally averaged summer haline structure for this variable ocean region when compared with the 29 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals similarities in sound-speed structure. Near surface and lower structure (below 300 m) are nearly identical. The linear appearance near the apex of the GDEM broad sound-channel axis is like that commonly observed in this region, as are sound-speed profiles having a little more curvature in the sonocline gradient as depicted by the typical. GDEM appears to reflect a reasonable seasonally averaged summer sound-speed structure for this variable ocean region when compared with the 29 usable observations.

- October to December:

An evaluation of the GDEM and typical temperature profile comparison reveals similarities in the thermal structures. Both general trends and numerical values are similar with the exception at 50 m. GDEM reveals a linear flattening between the 100 to 250 m region of the thermocline. The typical reveals a curvature. The GDEM linearity as a representation of the fall structuring is considered appropriate for this location. This is not to say that curvatures as depicted by the typical do not occur. Curvatures in profiles do occur and have been observed in this region; however, this has been observed in approximately 25 percent of the observations. GDEM appears to reflect a reasonable seasonally averaged fall thermal structure for this variable ocean region when compared with the 14 usable observations.

An evaluation of the GDEM and typical salinity profile comparison reveals general similarities in the haline structures. This region



has salinity characteristics in the fall of surface maximum, near-surface negative halocline with slight reversals to positive, returning to a slight negative. These characteristics are reflected not only in the averaged GDEM profile but also in the typical and envelope. The smooth curvature of gradient in GDEM around 100 m, as opposed to the abrupt inflection of the typical, is a characteristic of averaging. GDEM appears to reflect a reasonable seasonally averaged fall haline structure for this variable ocean region when compared with the 14 usable observations.

An evaluation of the GDEM and typical sound-speed profile comparison reveals similarities in the sound-speed structures. The linear flattening in the GDEM sonocline between 100 to 150 m is realistic and a commonly observed feature in fall for this location. This feature is present and appears on 10 out of 14 usable ocean station hydrocasts as well as in independent historical references. This area characteristically has a slightly deeper axis down to 300 to 350 m. The GDEM profile reflects this seasonal characteristic. GDEM appears to reflect a reasonable seasonally averaged fall sound-speed structure for this variable ocean region when compared with the 14 usable observations.

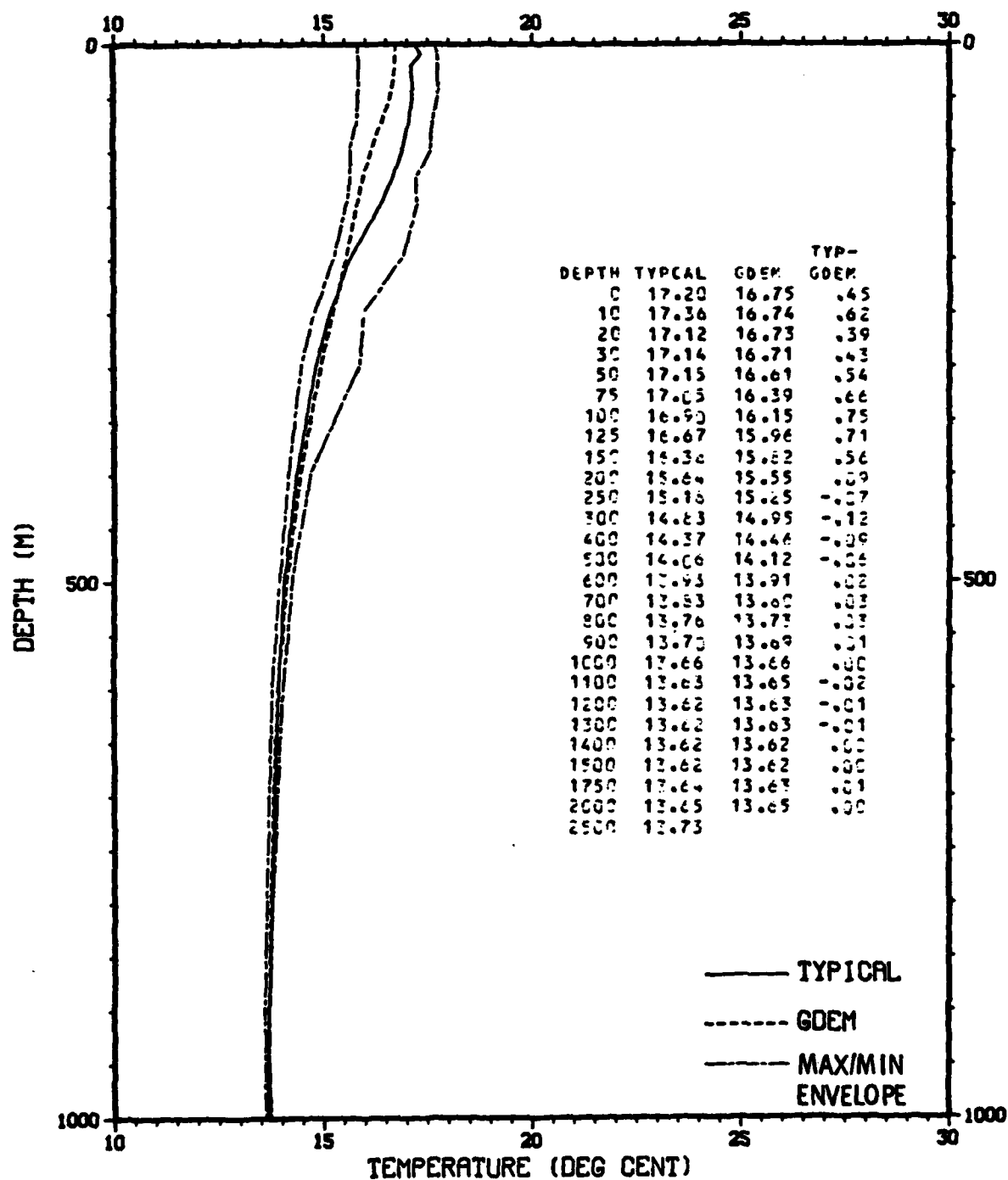


FIG. 7-1. VERTICAL TEMPERATURE PROFILE FOR LEVANTINE SEA (JAN - MAR)

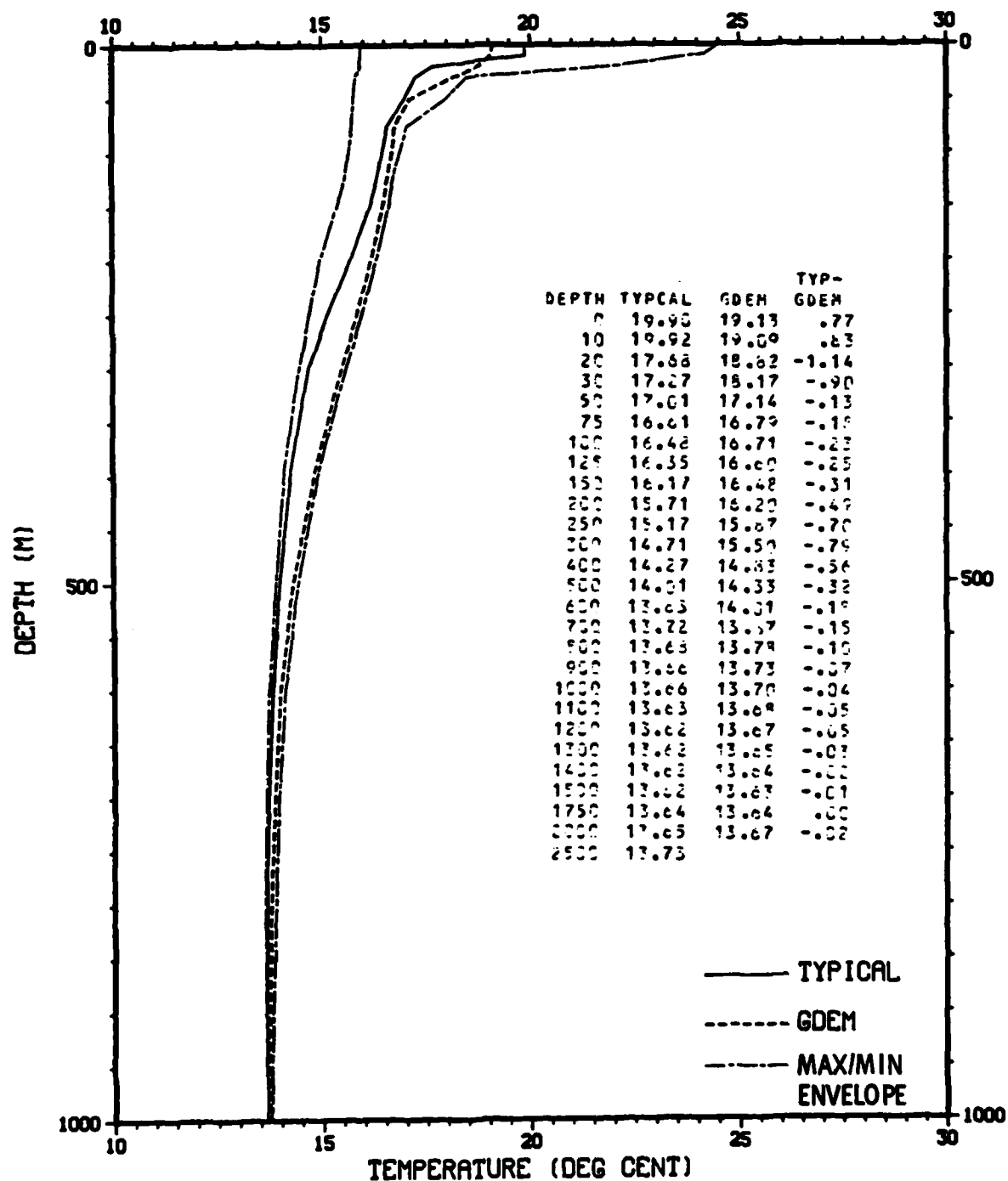


FIG. 7-2. VERTICAL TEMPERATURE PROFILE FOR LEVANTINE SEA (APR - JUN)

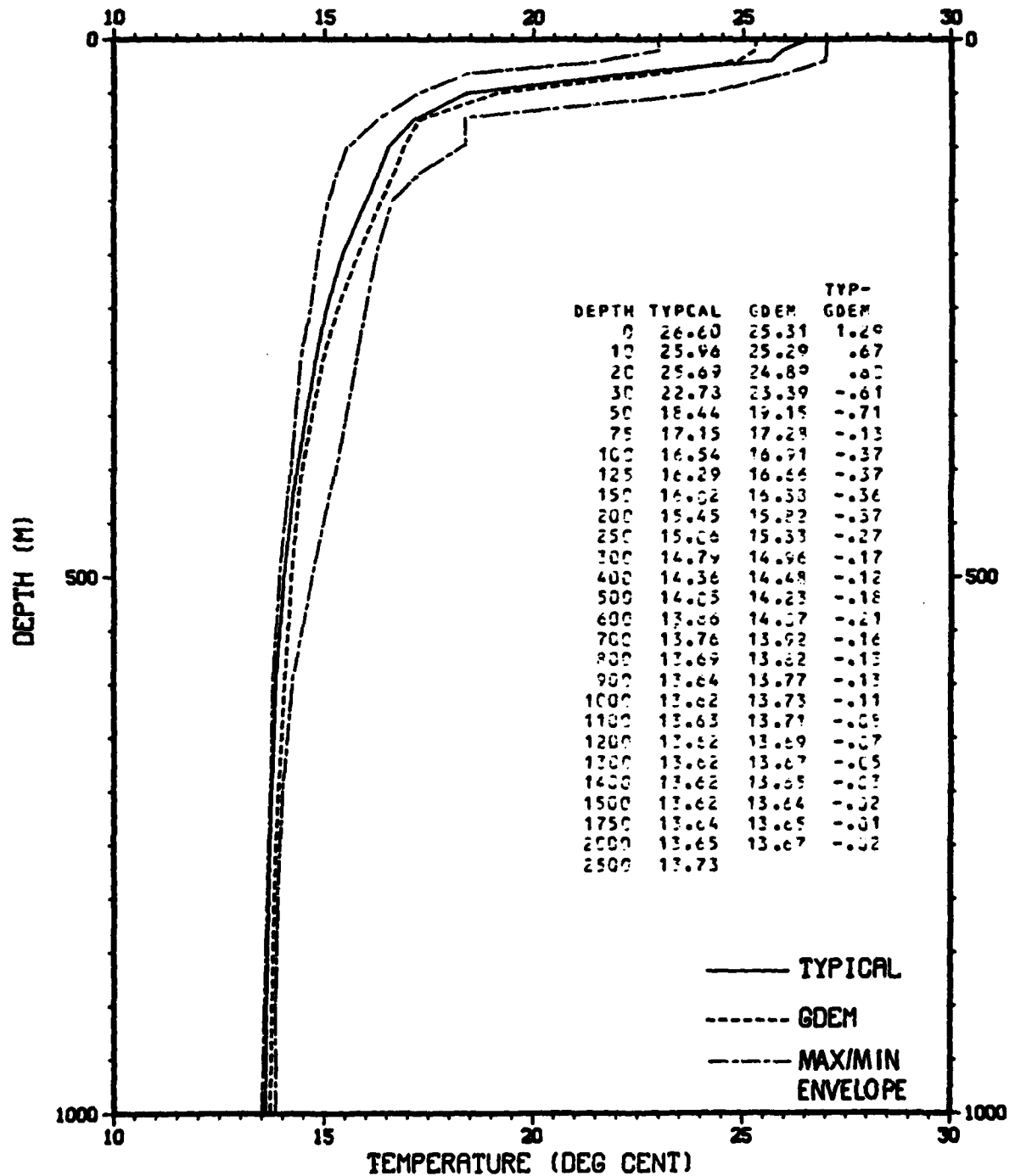


FIG. 7-3. VERTICAL TEMPERATURE PROFILE FOR LEVANTINE SEA (JUL - SEP)

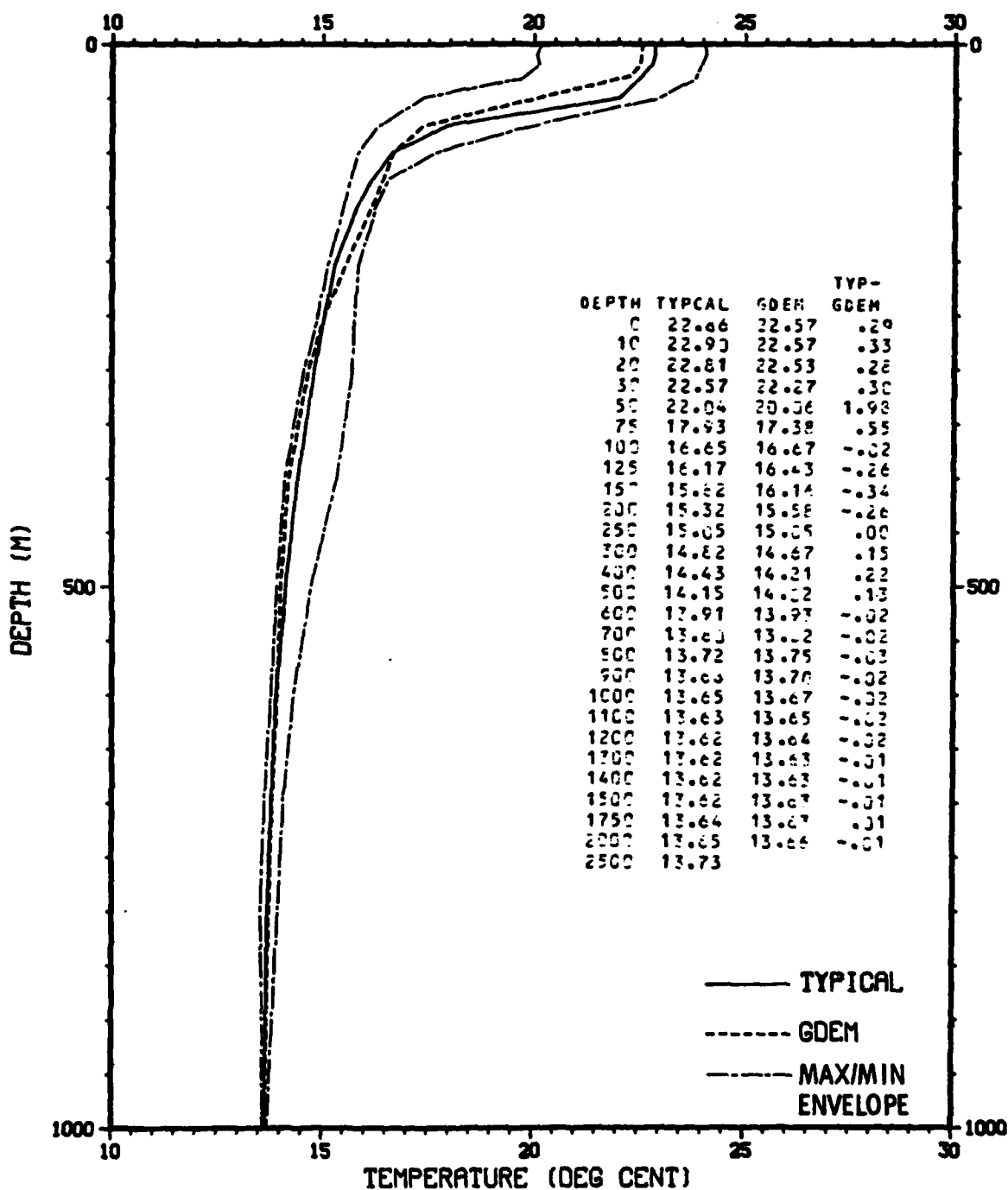


FIG. 7-4. VERTICAL TEMPERATURE PROFILE FOR LEVANTINE SEA (OCT - DEC)

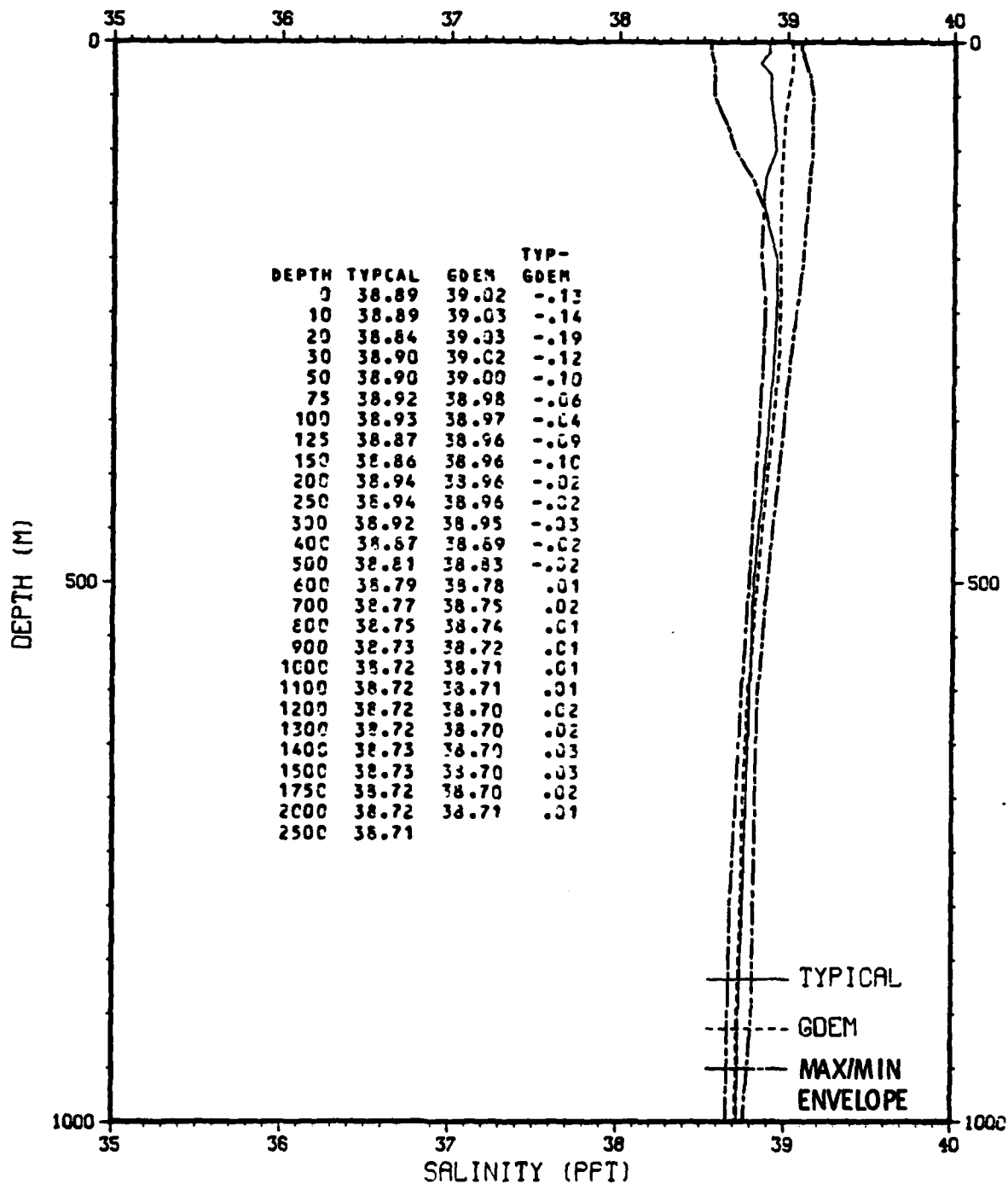


FIG. 7-5. VERTICAL SALINITY PROFILE FOR LEVANTINE SEA (JAN - MAR)

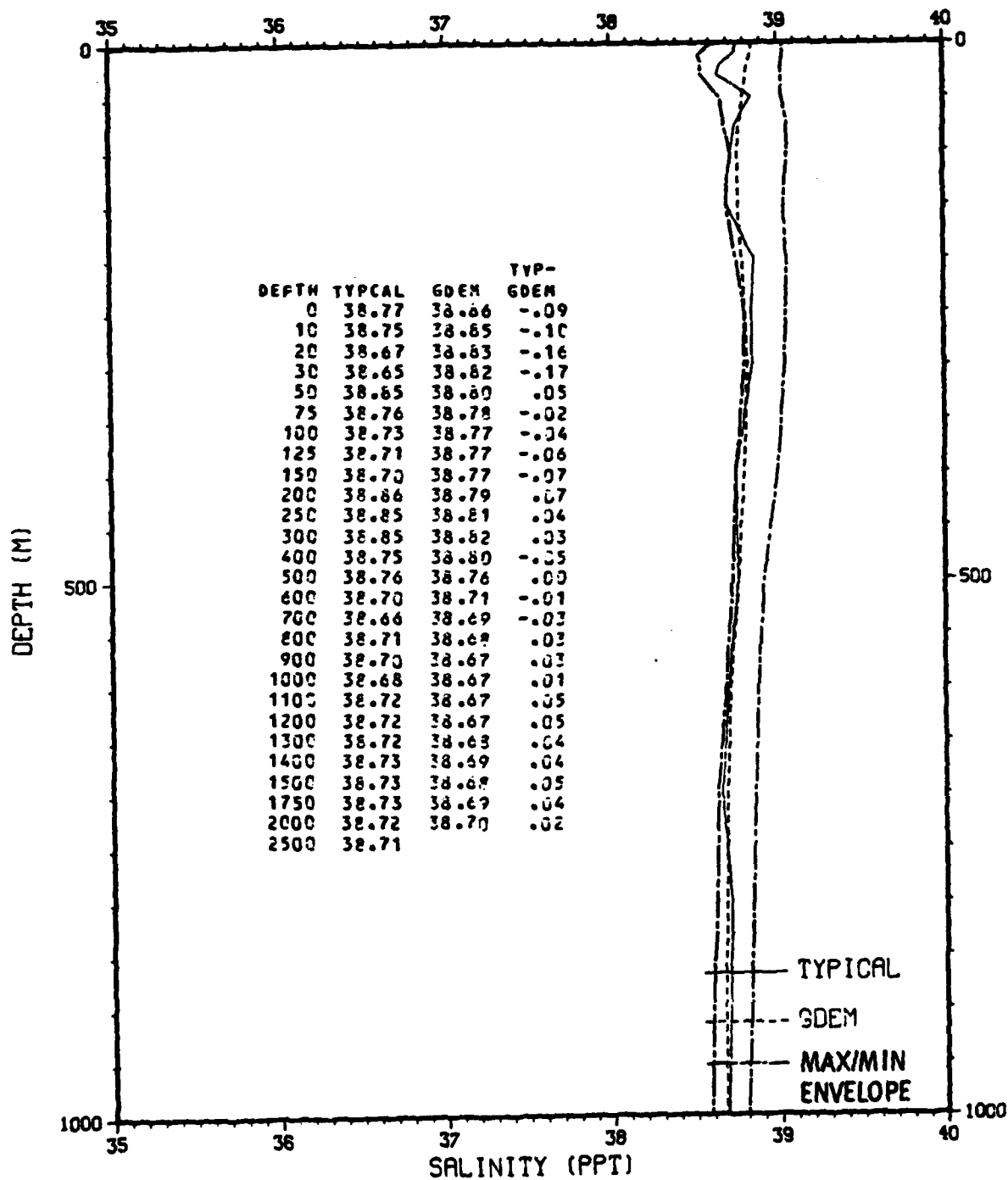


FIG. 7-6. VERTICAL SALINITY PROFILE FOR LEVANTINE SEA (APR - JUN)

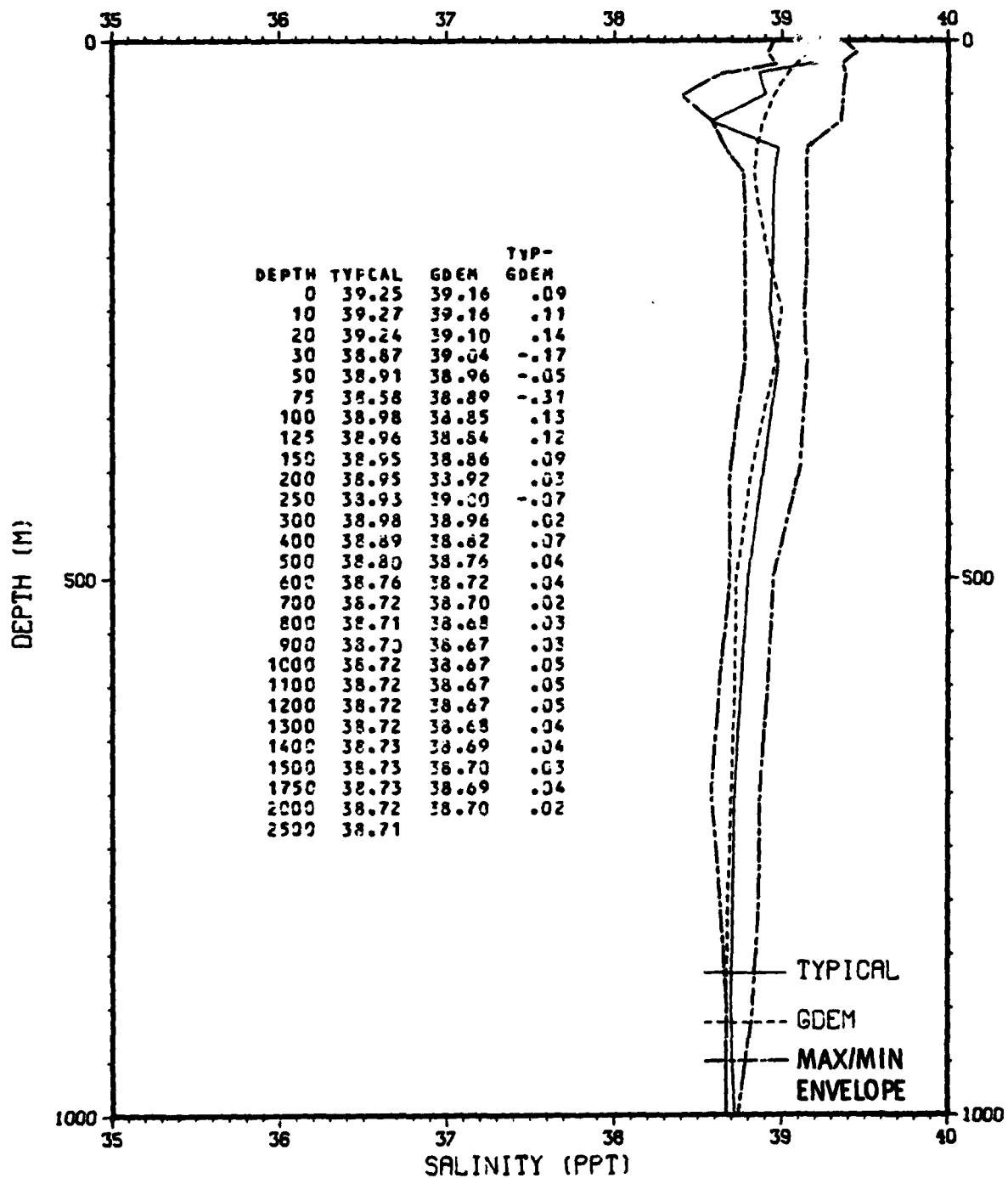


FIG. 7-7. VERTICAL SALINITY PROFILE FOR LEVANTINE SEA (JUL - SEP)



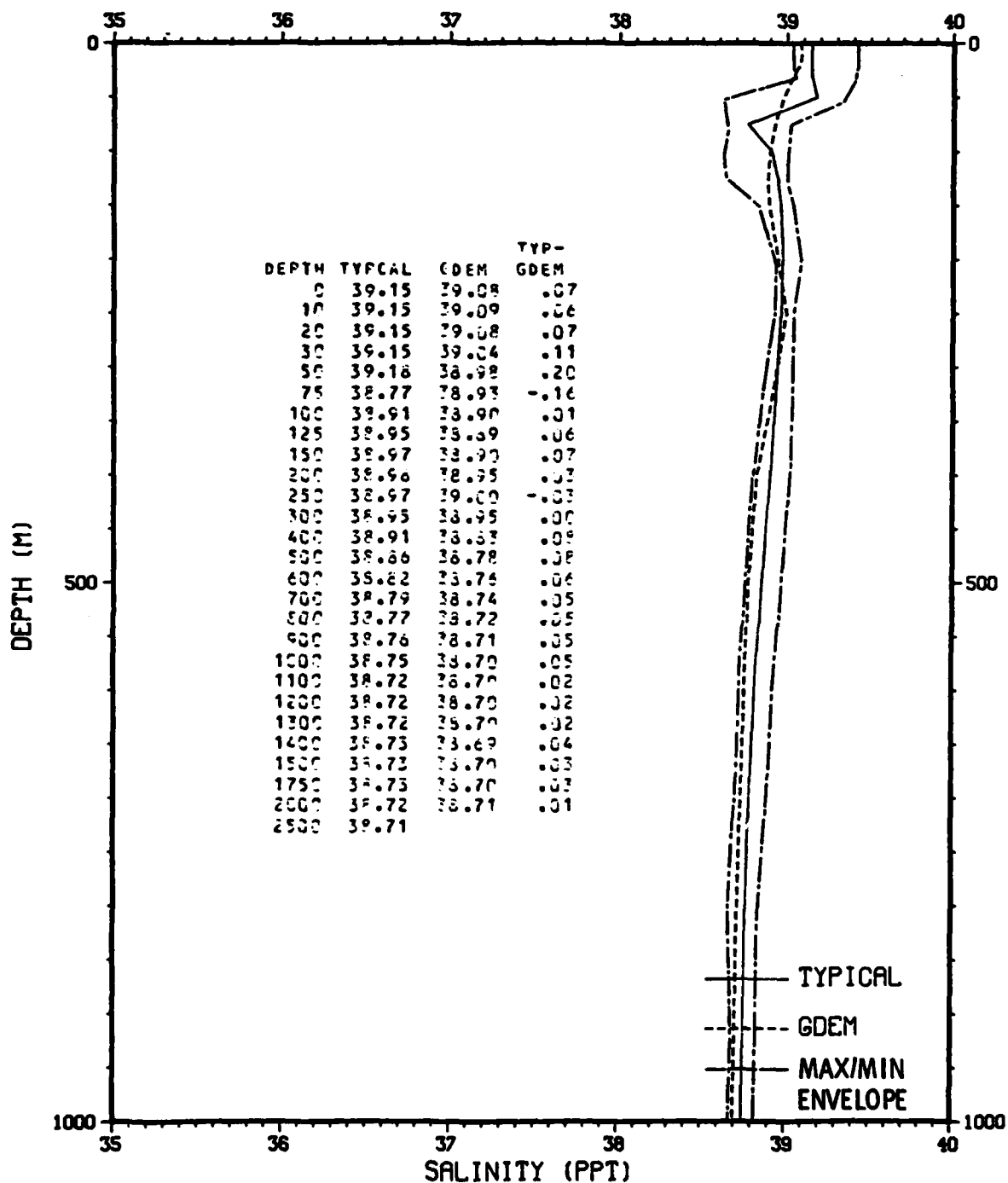


FIG. 7-8. VERTICAL SALINITY PROFILE FOR LEVANTINE SEA (OCT - DEC)

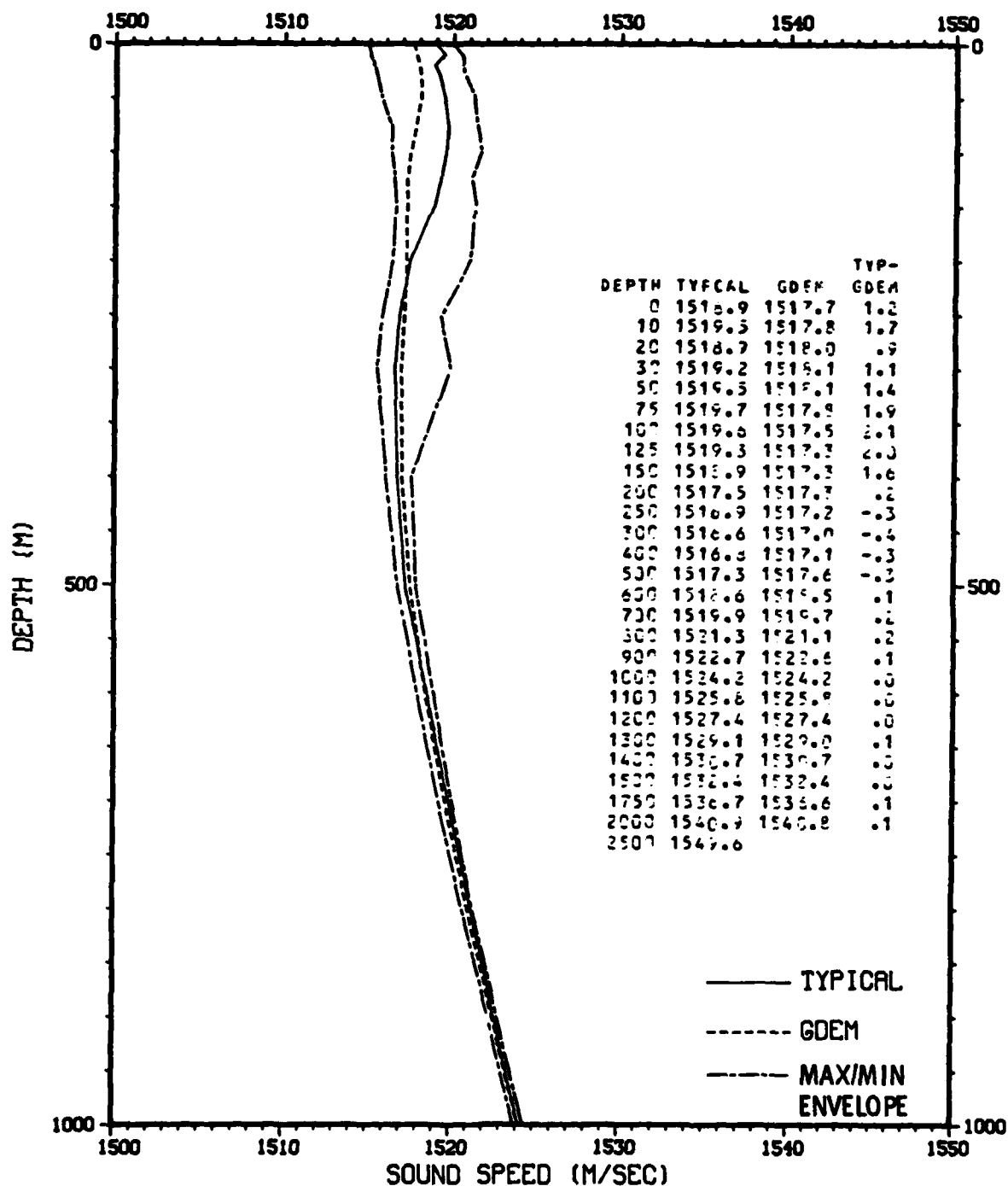


FIG. 7-9. VERTICAL SOUND-SPEED PROFILE FOR LEVANTINE SEA (JAN - MAR)

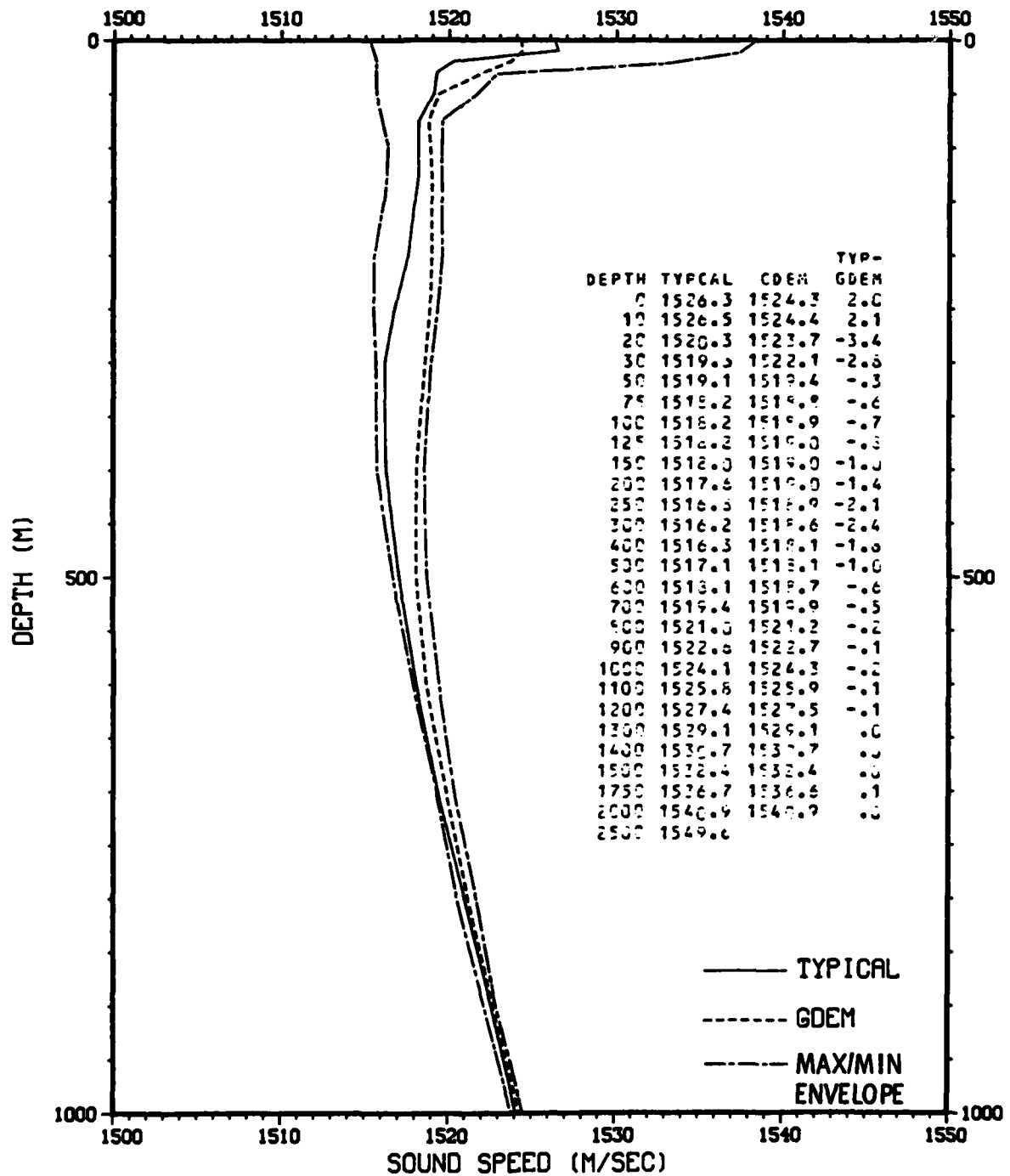


FIG. 7-10. VERTICAL SOUND-SPEED PROFILE FOR LEVANTINE SEA (APR - JUN)

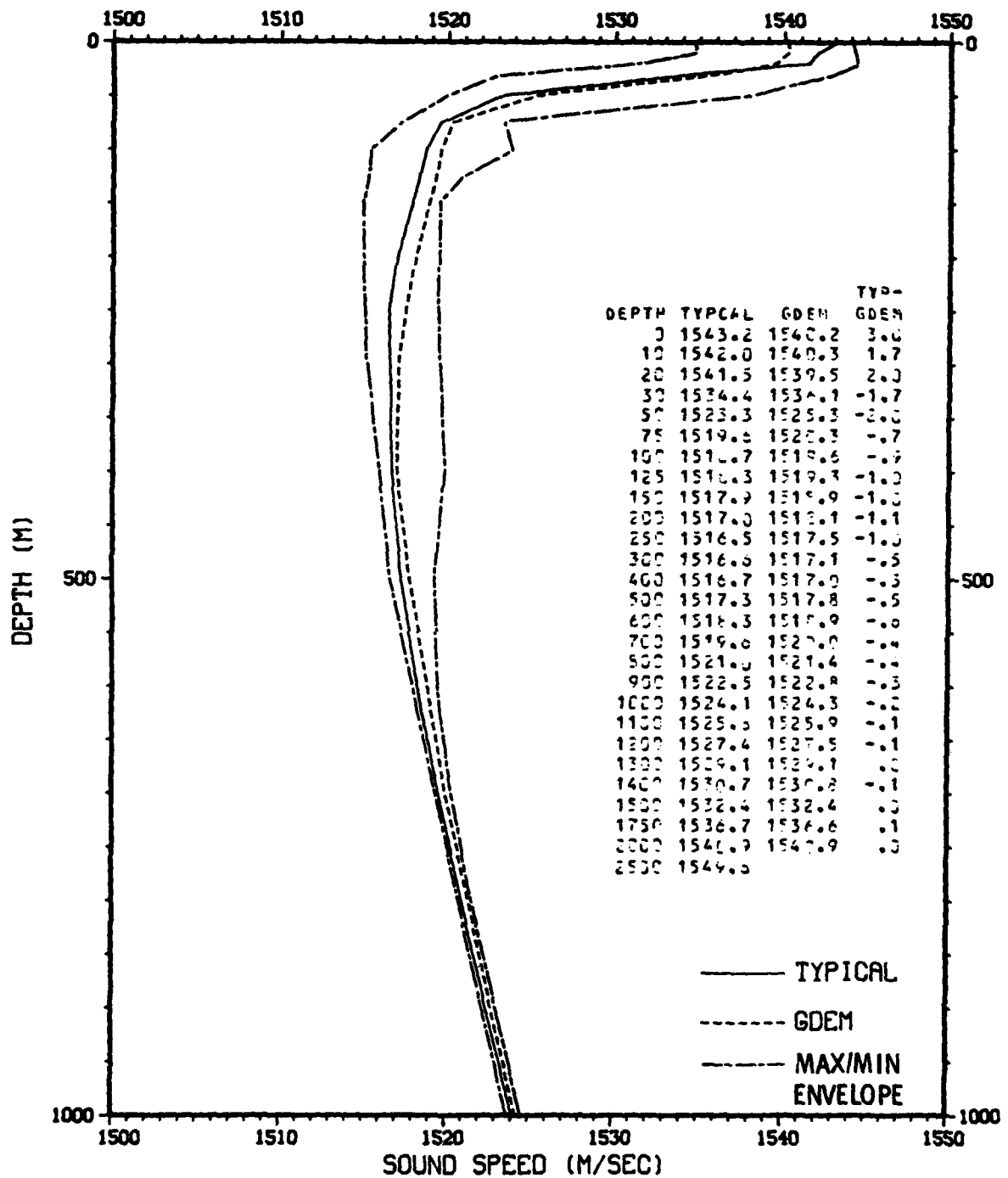


FIG. 7-11. VERTICAL SOUND-SPEED PROFILE FOR LEVANTINE SEA (JUL - SEP)

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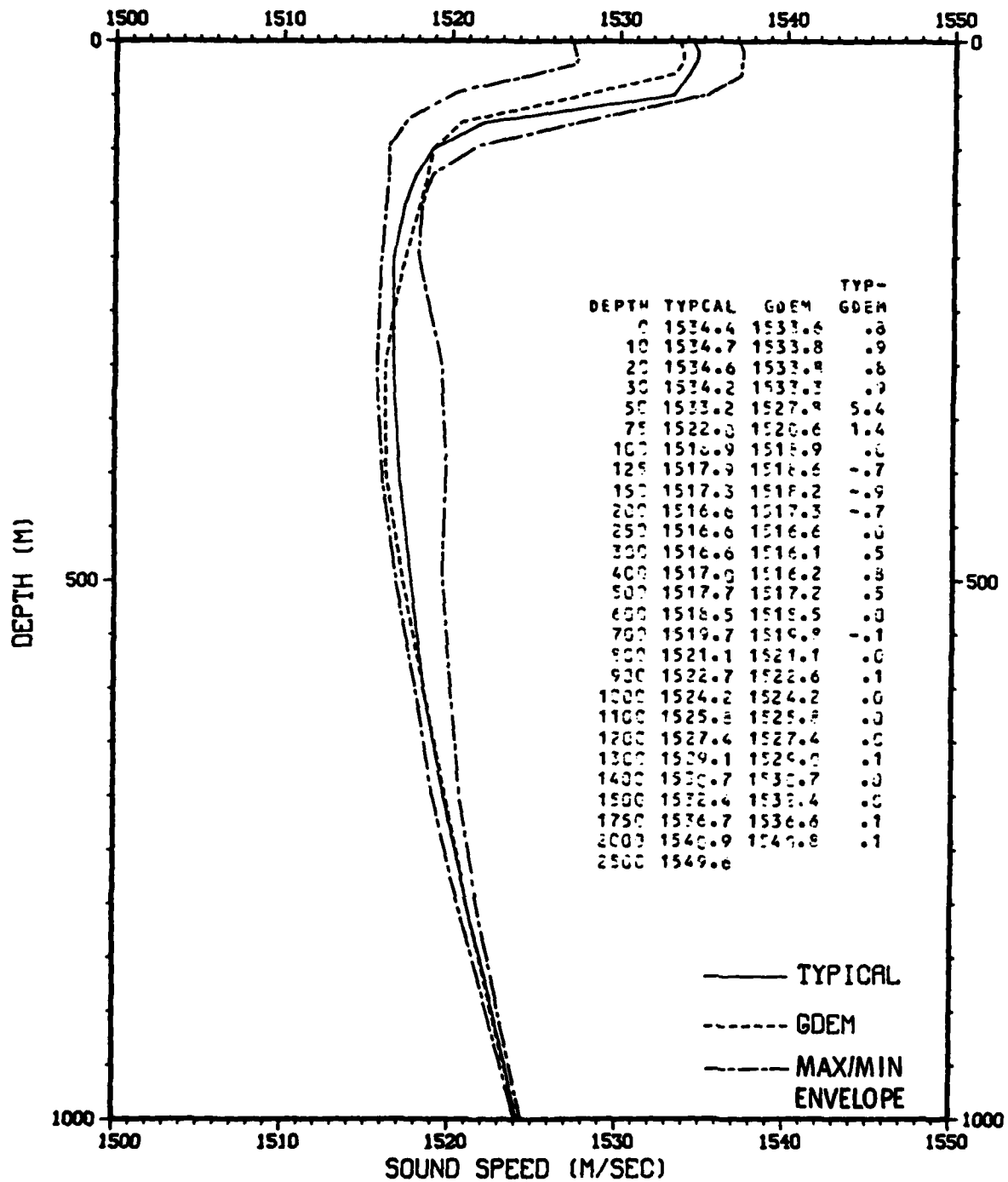


FIG. 7-12. VERTICAL SOUND-SPEED PROFILE FOR LEVANTINE SEA (OCT - DEC)

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Cheney, R.E., "Recent Observations of the Alboran Sea Front," Technical Note NOO TN 3700-73-77, Naval Oceanographic Office, NSTL Station, Mississippi, 1977.

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